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16. ABSTRACT

The project was undertaken in order to provide a feasibility study in developing and implementing a complete executive program to interface automatically various basin-wide water quality models for use by relatively inexperienced modelers.

This executive program should ultimately have the capability to integrate point source and nonpoint source models to simulate and analyze the consequences of implementing land use alternatives and pollution control strategies.

Interactive computer graphics display and software design to automatically interface the basin ecosystem submodels were studied to reflect accurately the present state-of-the-art.

A literature review was made to assess the state-of-the-art of urban water quality mathematical modeling relative to their modularization for the executive program. Particular attention was addressed to interactive computer graphic display as the medium in which this executive program would be primarily utilized.

A phased implementation program for the executive model development was suggested in cognizance of the current existing needs identified in this report.

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FEASIBILITY STUDY ON EXECUTIVE PROGRAM DEVELOPMENT FOR BASIN ECOSYSTEMS MODELING

by

Hubert Bouver
Department of Computer Science
State University of New York
Plattsburgh, New York 12901

Contract No. R804637

Project Officer

James W. Falco
Technology Development and Applications Branch
Environmental Research Laboratory
Athens, Georgia 30605

ENVIRONMENTAL RESEARCH LABORATORY
OFFICE OF RESEARCH AND DEVELOPMENT
U.S. ENVIRONMENTAL PROTECTION AGENCY
ATHENS, GEORGIA 30605

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FOREWORD

As environmental controls become more costly to implement and the penalties of judgment errors become more severe, environmental quality management requires more efficient analytical tools based on greater knowledge of the environmental phenomena to be managed. As part of this Laboratory's research on the occurrence, movement, transformation, impact, and control of environmental contaminants, the Technology Development and Applications Branch develops management or engineering tools to help pollution control officials achieve water quality goals through watershed management.

The use of complex mathematical models and the development of state-of-the-art models are increasing at a rapid pace. Consequently, efficient procedures are necessary to incorporate advances in the state-of-the-art into standard analysis procedures and to ensure that maximum information is obtained from model simulation at minimum cost.

This report presents the results of a feasibility study to assess the state-of-the-art of computer software and hardware as they relate to automating manual procedures for model modification, linkage, and execution and to organizing input and output data in an efficient format. The report is intended to provide guidance to researchers involved in the development of such computer software and hardware in support of environmental modeling efforts.

David W. Duttweiler
Director
Environmental Research Laboratory
Athens, Georgia

ABSTRACT

The feasibility of developing and implementing a complete graphic executive program to automatically interface various basin-wide water quality models for use by relatively inexperienced modelers was examined. Because of a number of problems, including data base management difficulties, the study recommends the development of a "pilot" version to resolve questions before full-scale implementation of the environmental system is attempted. The executive program should ultimately have the capability to integrate point and nonpoint source models to simulate and analyze the consequences of implementing land use alternatives and pollution control strategies.

To reflect accurately the present state of the art, the study examined interactive computer graphics display and software design to automatically interface basin ecosystem submodels. In addition, a literature review was made to assess the state of the art of urban water quality mathematical modeling relative to its modularization for the executive program. Particular attention was addressed to interactive computer graphic display as the medium in which this executive program would be primarily used.

This report was submitted in fulfillment of Grant Number R804637 by the State University of New York at Plattsburgh under the sponsorship of the U.S. Environmental Protection Agency. This report covers the period 1 July 1976 to 31 October 1976. Work was completed as of 30 November 1976.

CONTENTS

Foreword iii
Abstract iv
Acknowledgments vi

1. Introduction 1
2. Conclusions 3
3. Recommendations 5
4. Objectives and Approach 7
    Literature search 7
    Primary contacts 9
    Site visits 9
    Conferences 9
5. Results and Discussion 11
6. Description of the Graphic Executive Program 14
    The GEP components 14
    The GEP languages 17
    The GEP data structures 18
7. Summary 20
8. Bibliography 22

Appendices

A. Bibliographical Sources 36
B. Sample of Soliciting Letter 38
    Letter 38
    Abstract 39
C. List of Primary Contacts 40
D. List of Respondents 57
E. List of Participants 63
F. List of Trips to Conferences and Site Visits 66
    Conferences attended 66
    Travel made to the following sites 66
G. List of Computer Color Graphics Films 68

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SECTION 1

INTRODUCTION

The computer, one of the major technical innovations of our time, can be compared to a second industrial revolution, vastly magnifying and promoting man's ability to manipulate numbers, symbols and concepts. Computer graphics is the tool that emphasizes man-machine dialogue which takes place in real-time using an on-line display console with manual input devices. Graphic display is the medium in which the interactive executive program should be functioning. It shall be referred to, conceptually, as the "Graphic Executive Program for Basin Water Quality Modeling" or simply GEP.

The discovery and development of new knowledge and techniques, along with the discarding of the obsolete, continues at a fast pace in computer science and technology compared to other scientific and technical disciplines. A quantum jump has been made in the state-of-the-art of computer science from batch mode processing to computer color graphics display processing. It is with these new scientific developments and technological advancements in graphic processing, which have demonstrated additional capabilities in problem solving, that future direction of water quality modeling should evolve with a significant advancement in improving the development of models by utilizing the GEP system.

A development such as this should ease the fear of the computer graphics as a competitor to man and should create insights into the potential humanizing influences of the GEP system as it releases man from drudgery and enhances his ability to move into new directions.

This feasibility study on the development of a complete executive program for basin-wide area modeling was completed in four months. The materials in this report were gathered in basically four ways:

1. An extensive search of the literature (181 citations, Appendix A);

2. Soliciting information in a systematic attempt to recognize and evaluate effective methods for the development of the executive program (Appendices B, C, D and E);

3. Site visits to individual campuses and private organizations generating valuable discussions with many experts in this multidisciplinary field (Appendix F); and

4. Attending conferences in Washington, DC; Boston, MA; and Manhattan, NY (Appendices F and G) in which representatives from the various institutions identified themselves with aspects of the project's work, discussed major problems and issues concerning the feasibility of the executive program development.

SECTION 2

CONCLUSIONS

The "Graphic Executive Program for Basin Water Quality Modeling (GEP)" should be developed, implemented and oriented for a computer system designed to facilitate the preparation of water quality models on problem-solving units so that the trained technician who has little or no experience in computer programming can perform his tasks in a relatively efficient manner. In addition, trained technicians, experts, specialists and the like could also utilize the GEP system to develop, test and compare urban water models (Sonne et al., 1976).

In addition to its general applicability, the GEP system could be used:

a. to "browse" through output of computational processes, typically in the form of a graph prepared by the host computer;

b. to make cursory checks on specific iterative methods to determine computational validity;

c. to help represent complex interaction of results in three-dimensional viewing intensified by colors;

d. to use a common data base to evaluate comparative study of model developments to standards;

e. to terminate a run well before the foreseeable stopping rules required in batch processing could take effect;

f. to critically examine and adjust the system model at a glance;

g. to reduce calibration of models to simple "knob-turning" which will enhance the productivity of preparing a model for a new basin and, therefore, improve its portability.

It would be pretentious to claim that the GEP would be "all things to all people," but it would fill a much-needed gap in the field of water quality modeling. Despite the visual wizardry, there is no magic in computer graphics. The benefits provided by the GEP system to water quality modeling would be enormous and model development would be projected into the direction of a new era of computational power.

The objectives of this study are in direct compliance with the Federal Water Pollution Control Act Amendment of 1972 where the main thrust is to preserve the integrity of our national environment waterways and to recognize, protect and enhance its aesthetic value.

SECTION 3

RECOMMENDATIONS

Graphics system design is by nature a difficult subject. In the first place, it is less an analytical subject and more a matter of synthesizing a system design out of judiciously chosen hardware and software techniques. This report is an attempt to identify and point out the "ingredients" necessary to insure the development of a successful "Graphic Executive Program for Basin Water Quality Modeling (GEP)" system.

In many respects, it is true that research often tends to raise more questions than it can answer. While some questions have been answered, as a result of this study, new problems have been uncovered, leading to still more unanswered questions.

The basic recommendations of this feasibility study are as follows:

1. In view of all the considerable amount of information obtained on the present state-of-the-art of this multidisciplinary field, the complete development of the full-scale GEP system does not seem to be favorable at this time. As a desirable alternative, however, it is recommended, without reservation, that a "pilot" version for the development of the GEP system be undertaken. This prototype version would help clarify certain problems that have not fully been tested and demonstrated applicable to the GEP system. Before attempting to develop a full-scale model of the GEP system, these questions need to be resolved. In particular, the data base management still remains as the most difficult problem. Although Whinston (1975) and Grayman et al. (1975) have made some commanding break-throughs, their work needs to be tested in the GEP environmental system. There is a strong assurance that both of their methods would be successful which would, in turn, present another problem as to their selective evaluation for the GEP system.

2. It would be reasonable to expect a two-year period for the development of the pilot GEP system with a cost between $300,000 and $400,000. If the pilot program proved successful, another two years would be needed to develop a full-scale GEP system for about $500,000.

3. It is recommended that the original concept of the "GEP system should be operated by relatively inexperienced modelers" be changed to

"trained modelers," although expert modelers and the like would be able to use it.

4. The U.S. Environmental Protection Agency should provide a national user service center for the continuing development and utilization of the GEP system to implement and test newly developed models that would be utilized in the GEP system as potential additions to its water quality models library.

5. This phased implementation of the pilot program should be under the leadership of a tenacious project director who would be able to unify and collate the various expertise needed in development of the GEP system.

SECTION 4

OBJECTIVES AND APPROACH

The feasibility and optimal integration, simulation, and analysis of pollution control strategies rest crucially on several indispensable ingredients. The main thrust underlining the recommendations of this study constitutes an on-line interactive graphic model, a series of standardized modules of selected water quality models, and a calibrated dynamic data base structure. Endorsement was drawn from material gathered in basically four ways:

1. An extensive search of the literature;
2. Systematically soliciting information for the development of the GEP system;
3. Site visits to individual campuses and private organizations; and
4. Conference attendance.

LITERATURE SEARCH

Expansion of the search of all indices listed (Appendix A) would be unnecessarily extraneous and lengthy. The *Government Reports Announcement and Index* (*GRA*) will be used as a paradigm of the search process since work in this field is largely supported by the Federal Government. The *GRA* is the prime index of the National Technical Information Service's reports and documents.

First, regardless of the date of publication, the obvious identifiers were searched. The pertinent identifiers for the *GRA* search were:

1. Mathematical Models (predictive models, e.g., regression, deterministic, stochastic);
2. Environmental Modeling (e.g., loading, routing);
3. Water Quality Management (watershed management);
4. Water Pollution (in aquatic systems, basin-wide);

5. Water Quality Control (monitor);

6. Water Runoff (transport of pollutants on land and water);

7. Storm Water Runoff (agricultural runoff).

Though of narrower scope than the others, the last three identifiers were found to be quite important due to the extensive research accomplished in these areas. The inquiry focused next on specific and interrelated key words: water quality data, water quality standards, water reclamation, water resources, water storage, water supplies, watersheds, basin, rivers, stream flow, lakes, bays, estuaries, drainage, stream pollution, land use, irrigation, tributaries, eutrophication, hydrology, ecology, data processing-ecology and data processing-biology.

Proliferation and duplication of subclassifications generated for the most part irrelevant references encountered in searching pre-coordinated indices. Although there are obvious variations in vocabulary between the indices, those similarly structured were searched in much the same manner.

Of course, some indices are radically different. *Computing Reviews*, for example, is arranged in classified order and includes no description index. The following sections were explored issue by issue: Applications-Natural Sciences, Functions-Simulation and Modeling, and Functions-Graphics.

Certain indices were used as follow-ups to the prime indices. *Nuclear Science Abstracts* is cross-referenced by *GRA*. The *Science Citation Index* permits the tracing of key documents through the current literature.

All citations deemed pertinent were obtained either from the State University of New York's Plattsburgh Library or on inter-library loan through the North Country Reference and Research Resources Council. Some key documents were purchased, for example, from the Smithsonian Science Information Exchange (SSIE). The particular purchase of the standard formulary "Notice of Research Project" helped bridge the critical gap between the time a research project is initiated and the time its results are published by supplying information about on-going research in environmental science.

In addition to the facts obtained from on-going research, several custom searches were made for historical information of five years prior to the active file of selected principal or co-investigator names. Because of the limitation of facilities at hand, on-line data base searches performed were generally found to be less informative and often inadequate.

A few words about the bibliography are necessary. Approximately one-tenth of the total citations considered were included in the final bibliography. Moreover, due to the unusual circumstance of the three-month United Parcel strike, several pertinent documents and reports did not arrive in time to be considered. The final bibliography should be considered as a supplement to the most recent review which compiles, as of 1968, the state-of-the-art of urban water modeling with 161 citations by Sonnen et al. (1976).

PRIMARY CONTACTS

A postal campaign was systematically established to assemble the reactions of leading scientific investigators in their respective fields of expertise regarding the feasibility of the development of the GEP system. A mailing list of potential researchers to be contacted was compiled mainly from the following sources: university and research centers presently involved in environmental modeling; private firms as well as governmental agencies established in water quality modeling; and well-known and heavily referenced researchers obtained from the previously mentioned custom searches and extended reviews of the literature (Appendix A).

A sample of the soliciting letter, which explains the ultimate objective of developing and implementing an executive program to automatically interface various water quality models, may be found in Appendix B. The first mailing list of individuals and organizations potentially interested in the undertaking of the GEP system was composed for 281 recipients of which 68 responded. Each response was usually contacted further by telephone or, if that was not possible, by mail. Additional information was supplied to insure understanding of the conceptual development of the GEP system. Many responded favorably with other names of colleagues or research centers who they thought might also be interested in the feasibility study.

SITE VISITS

The exchange of information during lengthy telephone calls with the respondents lead to decisions on the selection of sites warranting a personal visit. An attempt was made to cover the whole spectrum of research vehicles actively engaged in the various aspects of inquiry or field work related to this study. Also, site visitations were organized to simultaneously minimize travel time and maximize the number of contacts and the amount of interaction with leading scientists. For an enumeration of the approximately 25 sites, see Appendix E.

CONFERENCES

A catalytic atmosphere is characteristic of conferences where systems or ideas of the state-of-the-art are discussed or displayed. These conferences provided a unique opportunity to search the basic and innovative areas crucial to the development of this system: predictive modeling, model verification, color graphics systems, and dynamic data base structure. During the course of the study, the most relevant conferences were attended:

1. Symposium on Nonbiological Transport and Transformation of Pollutants on Land and Water, National Bureau of Standards, Gaithersburg, MD, May 1976.

2. The 1976 National Computer Conference, New York, NY, June 1976.

3. The 1976 American Statistical Association, Boston, MA, August 1976.

The master control from the above innovative areas crucial to the GEP system is the utilization of computer color graphics systems. Graphics color display span an entire spectrum of application and are operational in a full range of computing devices from minicomputers to large processors. Realization of the power of color graphics as a conceptual tool that shatters psychophysiological limits with an incredibly responsive multidimensional model of instataneous comprehension is sweeping all of the leading scientific centers. For cognizance, color graphics stand alone. It has no rival for integrating a multidisciplinary endeavor as is demanded by the very nature of the GEP system.

The potential of computer graphics for applications to water quality modeling was exemplified, re-enforced and supported by the computer color graphics film presented to the U.S. Environmental Protection Agency in Athens, GA on 23 November 1976 along with the final report of this study.

SECTION 5

RESULTS AND DISCUSSION

This investigation is essentially embodied in discussions of the resolution of intellectual issues concerning the concepts necessary for the development of the GEP system consisting of integrated model modules and a dynamic calibrated data base enabling decision-makers to solve in real-time mode a given problem at a specified level of detail.

The first and most controversial theme usually encountered in the various consultations concerned the question of whether the present state-of-the-art was sufficiently advanced to support the development of a full-scale GEP system. Although the overall concept of the GEP system was very well received, unanswered questions about the dynamic data base structure, which is still unproven outside academic applications, highlighted this as the most difficult issue at hand. A full-scale system cannot be built only on the belief in a pedagogical model. However, as far as computer graphics itself -- hardware, software and languages -- is concerned, the power, knowledge and technology for implementation exist. A pilot study with a selected version of certain models was strongly indicated, which would emulate the concepts of the full-scale GEP system to test the "weak link" of the dynamic data base structure.

Consideration of this topic on the data base structure will be postponed until after the discussion of other issues that were of important concern but do not cause as much of a formidable problem as the data base structure. The questions these issues raised may already have their solution. They are definitely within our grasp or could be resolved with some study during the pilot phase.

The comprehensive objective of the GEP system requires a series of modularized models interacting with a dynamic calibrated data base structure exercised in graphic mode so that a decision-maker would be able to integrate an approach to a problem from a diverse selection of models and levels of resolution.

The inclusion of previously established models was encouraged with the intention of minimizing the cost of developing addition models. Without complete standardization of the parameters, however, the use of originally independent models leads to obvious difficulties in the comparison and coupling of these models. Modeling standards have been the objective of

widespread discussions on the effective appreciation of the nature and structure of different approaches of major methodological philosophies.

Various issues concerning the mechanics of integrating models have not been completely resolved with linkage in the GEP system. Raytheon Company, in an on-going pilot study, is attempting to integrate a watershed model, STORM, and a receiving water model, RECEIV II. Specific unanswered questions pertaining to the integration of various existing water quality models are concerned with the steady-state assumption in point source pollution which does not have an equivalent analogy in nonpoint source pollution.

In addition to dynamic capacitance, temporal and spatial resolution differences exist between models and could forseeably cause difficulties in the integration of the models. For example, the STORM watershed model needs only a few percentage estimates, whereas the SWMM model needs detailed information on every small pipe in the urban areas. Due to the complexity of some models, effective use of fudge factors for calibration of parameters would require an expert in that particular model. Recognition of the incompatibility of some models was unavoidable (e.g., QUAL I and QUAL II). On the other hand, QUAL II and the HEC river models and the Battelle and HEC reservoir models are obviously compatible.

A major dialogue concerning the use of outdated programming techniques in large complex programs that cost too much, run too slowly, take too much memory and operate inefficiently ensued. Remarks repeatedly surfaced included lack of advanced programming techniques such as structured programming, top down programming, module design interface, and data structuring. These techniques have been demonstrated to improve the quality of programs, and to be memory, time and money saving.

In most software systems, the central problems are reliability and maintainability. Past experience indicates that 50% of the time is spent on testing and more than 70% of the dollars in maintenance. In-depth techniques of structured testing were mentioned which identify software complexity, limit software complexity during development and test thoroughly against complexity. Structures testing and modularization techniques, which co-enforce the maintenance of standards of specification, design and code of software in GEP systems were also discussed.

The most recent conference on Comparative Data Base offered several dozen data base management systems -- none of which had the scientific orientation for handling a system like the GEP.

Scientific data structures for research in simulation and modeling are woefully behind business data base management systems, and in view of the severe limitations imposed, questions have been raised about it's primitive state.

Central in the foreseen evolution would be an emergence of a calibrated data base among interactive modules with easy recall in the form needed by the model for analysis or verification.

Desired characteristics for the GEP system would be efficient retrieval, searching, sorting, cross-referencing and recognition. Moreover, on-line language must allow many input-output operations. Specifically, it must possess powerful file-handling facilities while providing fast direct access to data base structures.

A canvass of expert opinions generated new approaches to data base structures that should be evaluated in the pilot phase. The whole concept of data base processing on large and small computers is still in a state of flux with many variant approaches, systems and methodologies available. Comparison of the configuration alternatives for data base processing demonstrates that the data base area allows more rapid equalization of capabilities across computer sizes and provides an opportunity for a viable processing partnership (minicomputer coupled to larger scale systems) which can synergistically produce more effective and powerful results than either processing approach could supply alone.

Aspects of a centralized data base often impose constraints upon the organization when sources or users of data occur at widely dispersed geographical locations. The concept of distributed data base addresses this constraint.

The development of a general-purpose data base broad enough to allow a wide variety of existing models to work off it might be more practical than trying to design a data base to fit existing models (i.e., tailoring data base to individual models).

The ultimate approach in future water quality modeling has been established as color graphics display. Its awesome potential in visual thinking liberates cognitive abilities invaluable in the development of future environmental models. There is inherent power in instantaneous grasp of multi-faceted systems with immediate feedback to on-line manipulation. A by-product would be the elimination of unnecessary restraints on creativity.

SECTION 6

DESCRIPTION OF THE GRAPHIC EXECUTIVE PROGRAM

THE GEP COMPONENTS

The outcry for unification of mathematical modeling development and interactive graphic executive program could well be the next advancement in the state-of-the-art of water quality modeling. It is one of the most fascinating devices that computer technology has produced.

The GEP system could be equipped with the following devices to provide the maximum capability for solving water quality problems:

1. *Console*: a visual display unit that provides a "window into the computer." The console display overcomes most of the disadvantages of a typewriter terminal. Its display rate is very fast -- thousands of characters per second. It is quiet with high-speed refresh buffer (30 times a second). Its output is flexible, easily modified and rearranged. It has pictorial capabilities allowing line segments to be displayed in colors. Pointing facilities, such as a light pen, allows users to easily designate symbols or vectors of interest. It has fixed and variable function keys. When depressed, they transmit a signal to the computer which can be equated with a prestored functional program. Function keys such as the joystick, control dials, and trackball, provide convenience and ease of operation and enables the user to change information under program control and, thus, by saving user action, increases the overall response rate many-fold.

2. *Alphanumeric Keyboard*: is an electromechanical device that is used as an entry to effect manual input to a graphic display system. It handles alphanumeric code, including the upper and lower case alphabet, numbers and as many as 32 control functions having code-generating options into the display control register and sets priority condition interrupt.

3. *Function Switch Keyboard*: provides a flexible means of communicating with the computer inputting certain types of often repeated data and control commands. It also has the capability to specify software control of any of the display system functions such as menu selection, peripheral device selection, subroutine calling and

control of input-output operations. The function switch keyboard may be placed under complete software program control to set up any series of interrupt flags, e.g., character size, vector modes, color change, degree of rotation, etc. Illumination of the switches under program control may be used to verify servicing, selection of options, available subroutines, etc. Switch configuration may be usually expanded in groups of 12, to a maximum of 64 switches for selections.

4. *Light Pen*: incorporates a photo-sensing device, preamplifier and touch-sensing electronics designed for symbol sensing and editing functions. The position of the pen in any pattern may be continuously computed from the pen's response to the pattern, hence, allowing the computer to maintain all coordinates on the display.

5. *Joystick*: is an electromechanical device that has been designed to perform cursor positioning and provides a means of manually entering two- or three-dimensional information into a graphic display system. It operates as an incrementing or decrementing analog device in modifying the system translation registers of X, Y and Z.

6. *Control Dials*: are electromechanical analog devices containing an array of as many as one dozen potentiometers designed to allow an operator to modify a register for continously changing program variables or critical parameters on a display screen. The position of each potentiometer is converted to digital values and may be sampled by the system processor.

7. *Trackball*: is a functional two-axis mechanical device that provides accurate X and Y pulse train outputs proportional to a continuously free and smooth rotation of a 4-inch ball. Rotation of the ball is translated to two magnetic encoders displaced by 90 degrees within the case. The trackball is used to provide relatively high accuracy X and Y positioning of a cursor on a screen. These pulse trains are accumulated in the controller and may be interrogated at any time to provide relative position information.

In addition, the console display processor should contain such capabilities as the following:

1. *Smoothing*: provides the ability to draw arcs with a series of small incremental vectors.

2. *Zooming*: provides the ability to magnify or reduce the extracted data displayed on the CRT to provide "zoom-in" or "zoom-out" effect.

3. *Windowing*: allows a three-dimensional portion of the data base to be extracted and presented for viewing within a designated area on the CRT.

4. *Clipping*: provides the ability to concatenate the transformation and removes the lines that are off the window boundary parameters.

5. *Transforming*: provides the ability to modify a display image by scaling, displacement and/or rotation.

6. *Transformation Read-Back*: provides the capability to access final transformation element angles when performing multiple rotations.

7. *Edit*: provides the ability to insert, delete and adjust displayed elements on the screen.

8. *Select*: provides the user with the ability to highlight (brighten) as well as color elements on the screen for identification.

9. *Calculator Mode*: provides the user with the ability to perform short calculations.

10. *Pick/Hit*: provides the user with the ability to select input devices such as a function key which, when depressed, transmits a signal to the computer which can be equated to a prestored typewriter message of many strokes, thus saving user action by providing convenience and ease of operation and increasing response rate.

Color Graphic Display

The study of color perception has led to the development of an interdisciplinary field known as color psychophysics, which attempts to explain the observed phychological effects of color on a human observer in terms of a physical model. In pseudocolor processing, each shade in a gray-tone digital image is assigned a separate color for display purposes. The motivation for this type of enhancement is based on the knowledge that the human eye can simultaneously discern many more shades of color that shades of gray. Depending upon the choice of color assignment, perception of information in an image may be greatly increased by the use of pseudocolor.

Additional Devices

If desired, devices using microfilm cameras can be used to transfer any displayed picture onto microfilm for a hard copy representation of film viewing to be used later for further examination.

Benefits

Hardware prices are coming down steadily and, as more users switch to on-line "thinking, creating and manipulating," it is hoped that this use of computers will become increasingly accepted and judged cost-effective to the same extent that numerical and data processing applications are already considered to be legitimate uses of the computer.

Host Computer to GEP

The old concepts of economy of scale in computing and desirability of centralizing all computing in a few places are no longer valid. Computing costs, for example, are dropping much more rapidly than communication costs. It is to be expected that future computing will be distributed with respect to both computing power and mass storage. Each level of the distributed hierarchy will do that which it can perform in the most cost-effective fashion. Large host computers will emphasize common data bases, common problems, global information, and really large-scale number crunching such as the GEP system with a signficant spectrum of models.

THE GEP LANGUAGES

In spite of fingertip capabilities, the GEP system must provide not only graphics facilities, but also a good high-level language, accompanied by a powerful data structure facility, selective software richness, and aids to debugging and editing.

All functions of the GEP system have to be done quickly and automatically. The user should not be encumbered with the problem of translating the graphic image and all the manipulating commands into mathematical terms and then into computer language. This is the task of the control unit and the computer hardware as well as software. If the control unit and computer software execute these functions, the user can concentrate on the procedure and minimize efforts on developing computer programs. The use of problem-oriented languages will continue to expand because specialists in every discipline want to communicate with the computer in languages that are comfortable for them to use and which provide them with the greatest degree of expressiveness possible. It is reasonable to press for a user-defined language. In this way, the personal preference of the specific user could be satisfied.

If the use of computers is to grow as rapidly as it has in the past, procedure-oriented language will be forced to change, unless the entire scientific population is to consist of programmers. One may reasonably expect ALGOL, PL/I, FORTRAN and COBOL to be in use for many years -- with evolutionary modification, to be sure -- but revolutionary new developments are less of a distinct possibility. PL/I was developed with the characteristics of ALGOL, COBOL and FORTRAN, and presumably with the intention that it could replace them. The use of FORTRAN, however, persists because of its availability on virtually every computer. It would be naive to think that FORTRAN is truly a machine-independent language. It is seldom possible to transfer FORTRAN programs between machines without the need of an extensive FORTRAN-converter design for large-scale conventional computers. FORTRAN offers few program structure facilities of any worth: its subprograms are non-recursive and require unusual conventions regarding the passing of parameters; the IF statement is clumsy and lacks the ELSE clause, the iterative DO loop is limited in its usefulness. The design of FORTRAN has scarcely been modified since its conception in the Fifty's. PL/I is by far the "richest" procedure-oriented language now available. It provides the

programmer with the most features for handling a large variety of applications in a variety of ways and it can be used effectively for both scientific and data processing applications.

The software requirement for real-time applications of the GEP dictated the need for certain kinds of software components typically present in real-time application. Among them are those for describing the layout of pictures (picture-plotting software), decoding user input (attention-handling software) and subsequent picture transformations, alterations and manipulations (picture-editing software). Additionally, the scenario showed the need for data structure and data base handling software. The search-strategies package of the GEP system should include syntactic components based on a stored grammar and dictionary; a semantic interpreter that transforms the syntactically analyzed input into a formal query statement; and a deductive component that can generate responses by comparing the formalized query statement with information included in the data base.

In contrast with tremendous advances in machine speed, miniaturization, and versatility, the basic level at which most machine languages operate, has changed relatively little over the past two decades. As the development of water quality modeling becomes more complex and more sophisticated, the primary and increasing concern still remains the problem of selecting a high level language.

Interactive Dialogue

It is surprisingly difficult to construct a good dialogue between the user and the programmer because it involves knowledge of human factors, a subject generally unknown to the programmer. When designing an interactive dialogue, however, it is of particular importance to always keep the user in mind. For instance, as the user gradually gains experience in the use of the GEP system, he would become more familiar with the procedure and, thus, would have less need for simple commands and explanatory text displays and error messages that helped him along in a simplified fashion at first. At some point, he should be allowed to tailor the degree of assistance he receives to suit his level of competence. This would allow the user great flexibility to type as much or as little of the concise commands for "experts" as he wishes. Another important aspect is that the user should not be harshly penalized for erroneous input. He should be allowed to re-enter the incorrect element. The GEP system should respond to illegal or incorrect commands with helpful messages. It is essential that a good general strategy of error recovery be adopted along with a clear, well-structured command language having the main qualities of simplicity and consistency.

THE GEP DATA STRUCTURES

A language that is to be used for interactive applications must allow a wide range of input/output operations; it must also possess powerful file-handling facilities while providing rapid access to large data structures.

Conventional arrays and vectors are essentially "static" data structures and do not perform well in interactive situations. Interactive programs like the GEP system would call for extremely "dynamic" data structures that expand and contract during the program's execution. In addition to easy accessibility and flexibility in expansion of data file, the GEP should have the ability to manipulate easily individual bits of information such as storing, extracting, exchanging or modifying the information.

Just as the communications package aims for terminal transparency, the data-base management package seeks to provide program independence by separating the application programs from the file data on which they operate. This permits the data base to be modified or reorganized without unduly affecting the application programs since all requests for data are "filtered" through the data-base management package. This is in marked contrast to the earlier practice in which the application programmer was free to design his own files and records and embed references to these records within his program where he, unconstrained by outside standards, found it convenient. Such a practice is intolerable in the GEP system in which files frequently must be expanded or be reorganized, based on their degree of usage, with data shifted from one physical storage medium to another. The objective of program independence is to permit these changes to the data base without requiring inordinate changes in the application programs that reference the data base.

The major objectives of grouping data items into data sets are efficient retrieval, searching, sorting and recognition. Searches, for example, may be expedited by searching the "Table of Contents" for data set labels exhibiting desired characteristics, and then searching for data items with more specific characteristics among only those data sets whose labels passed the first search.

The set concept represents a new organizing force whose potential is just beginning to be realized. If the natural world is considered in terms of the entities that exist, the attributes that describe them, and the relationships that associate them, then the equivalent information system concepts are record, field and set, respectively.

SECTION 7

SUMMARY

Since the main recommendation is to develop a pilot version of the GEP system, a proper selection of well-known water quality models would be needed. In this selection, models should be compatible so that they could be interchanged readily for a comparative study of the results. Research in the evaluation of the "best" models for various levels of basin analysis is being conducted by the U.S. Army Corps of Engineers in Vicksburg, MS. Resource Management Associates in Lafayette, CA (Appendix D) is also presently evaluating lake models. Their conclusions should reflect the selection of these various models to the GEP system. This GEP system should be designed as a modular system of subprograms of the water quality models where the state-of-the-art processes and procedures could be easily implemented or altered. It is well known that a tool is only good if it continues to be useful although constant modification and updating are taking place. A programming package usually becomes obsolete when the implementing and debugging phases cease.

In addition to the recommendations presented by Sonnen et al. (1976) to define the next generation of models in future urban water model development and by Mar and Butcher (1974) on problems encountered in multidisciplinary research, future design of models should observe a standardization in the development of their input-output list of parameters. Since specific and basic kinds of parameters could be determined and identified for each type of model, standards for their use should be proposed. This would help future development of systems such as the GEP and facilitate the conceptual design of their common data base and improve the linkage possibility to even greater capability. The GEP system would enable the user to "tune up" a water quality model more efficiently than could be done using a batch processing model. The GEP system would obtain the required input by "interrogating" the user. He would then respond by any of the functions desired. Basic questions would be of the following type: "How many square miles is the basin?" or "What is the frequency of rain fall data?". These interrogative questions would help to identify the criteria needed to base a selection on the model best suited for the particular study of a given basin.

For the verification process, the modeler should establish confidence limits or bounds around the output of his model. He should also spell out confidence limits of all parameters to those who are not familiar with the model's limitations. Too many times, unwarranted decisions are deduced. The average person who is not familiar with modeling has the tendency to accept

the data as the "gospel" because the data was scientifically "created" by a computer that has "mystical" powers and seldom makes mistakes. It is for this reason that only trained modelers should use the GEP system. The modeler with intuitive knowledge of the system, however, still requires the means to critically examine and adjust the system models. Intuitive guidance of model exploration using the GEP system would result in substantial savings; the user often could terminate a run well before the foreseeable stopping rules required in batch processing would take effect.

This study did not find any individual, institution, firm or university that has all the necessary capability and expertise to undertake the development of the pilot version of the GEP system. For this reason, it recommended strongly that a "strong" project director be appointed to merge the various identified expertises and unify these multidisciplinary fields into a well-orchestrated group of experts in integrating the diverse activities required to accomplish the pilot version of the GEP system.

SECTION 8

BIBLIOGRAPHY

Abbott, J. 1976. Guidelines for Calibration and Application of the Urban Storm Water Runoff Program (STORM). U.S. Army, Corps of Engineers, Hydrologic Engineering Center, Davis, CA.

Advances in Environmental Sciences. 1969-73. New York, Wiley-Interscience.

AFIPS National Computer Conference, Proceedings. 1976. Winkler, S. (ed.). Montvale (NJ), AFIPS Press.

Albertson, M.L., N.S. Grigg, J.W. Labadie, H.G. Wenzel, and G.L. Smith. 1974. Metropolitan Water Intelligence Systems. Department of Civil Engineering, Colorado State University, Fort Collins, CO. NTIS Number PB-235 532.

Alger, P.L. 1969. Mathematics for Science and Engineering. 2nd ed. New York, McGraw-Hill Book Company.

Amy, G., R. Pitt, R. Singh, W.L. Bradford, and M.B. LaGraff. 1974. Water Quality Management Planning for Urban Runoff. EPA-440/9-75-004. URS Research Company, San Mateo, CA.

Anderson, E.A. and N.H. Crawford. 1964. The Synthesis of Continuous Snowmelt Runoff Hydrographs on a Digital Computer. Technical Report 36. Department of Civil Engineering, Stanford University, Stanford, CA.

Arbabi, M. and J. Elzinga. 1975. General Linear Approach to Stream Water Quality Modeling. Water Resources Research. 11:191-196.

Association for Computing Machinery Symposium on Symbolic and Algebraic Computation, Proceedings. 1976. Jenks, R.D. (ed.). New York, Association for Computing Machinery.

Ayars, J.E. 1976. Adaptation of a Digital Model for Assessing the Impacts of Land Use and Treatment Upon the Hydrologic Response and Water Pollution Potentials of Drainage Basins in Maryland. Department of Agricultural Engineering, University of Maryland, College Park, MD. (Preliminary Proposal).

Baca, R.G., M.W. Waddel, C.R. Cole, A. Brandstetter, and D.B. Cearlock. 1973. EXPLORE-I: A River Basin Water Quality Model. Pacific Northwest Laboratories, Battelle Memorial Institute, Richland, WA. (EPA Contract Number 68-01-0056).

Baca, R.G., M.W. Waddel, C.R. Cole, A. Brandstetter, and D.B. Cearlock. 1973. Appendix A: Literature Review. Pacific Northwest Laboratories, Battelle Memorial Institute, Richland, WA. (EPA Contract Number 68-01-0056).

Baca, R.G., M.W. Waddel, C.R. Cole, A. Brandstetter, and D.B. Cearlock. 1973. Appendix B: Programmer's Manual. Pacific Northwest Laboratories, Battelle Memorial Institute, Richland, WA. (EPA Contract Number 68-01-0056).

Baca, R.G., M.W. Lorenzen, R.D. Mudd, and L.V. Kimmel. 1974. A Generalized Water Quality Model for Eutrophic Lakes and Reservoirs. Pacific Northwest Laboratories, Battelle Memorial Institute, Richland, WA. (EPA Project Number 21lB0162).

Baca, R.G. 1975. Finite Element Methods for a Class of Problems in Mass, Momentum and Energy Transport. Pacific Northwest Laboratories, Battelle Memorial Institute, Richland, WA.

Barrow, D.R. 1973. SIDES: STORET Input Data Editing System. U.S. Environmental Protection Agency, Surveillance and Analysis Division, Region IV, Athens, GA. NTIS Number PB-235 532.

Batteke, J.P.H., D.M. Heaps, and M.S. Mercier. 1974. Canadian Water Resources Information: A Network Approach. Information Storage and Retrieval. 10:85-99.

Bell, M.C. and B.W. Mar. 1974. Model Development and Systems Analysis of the Yakima River Basin: Fisheries. Report Number 17F. Water Research Center, Pullman, WA.

Betchart, W.B. 1974. Model Development and Systems Analysis of the Yakima River Basin: Water Quality Modeling. Report Number 17D. Water Research Center, Pullman, WA.

Betson, R.P. and W.M. McMaster. 1975. Nonpoint Source Mineral Water Quality Model. Water Pollution Control Federation Journal. 47:2461-2473.

Bonczek, R.H. and A.B. Whinston. 1976. A Generalized Mapping Language for Network Data Structures. NSF Grant Number ENG 75-07845. Purdue University, Lafayette, IN.

Bonczek, R.H., C. Hosapple, and A. Whinston. 1976. Implementation of a Decision Support for Regional Water Quality Planning. Purdue University, Lafayette, IN. (OWRT Grant Number 6538-62-1310).

Bonczek, R.H., C. Holsapple, and A. Whinston. 1976. Extensions and Corrections for the CODASYL Approach to Data Base Management. Purdue University, Lafayette, IN. (OWRT Grant Number 6538-62-1310).

Boyd, D.W. and T.T. Williams. 1976. Development of a State Water-Planning Model: I. Methodology. Report Number 15. Montana State University, Bozeman, MT.

Boyd, D.W. and T.T. Williams. 1976. Development of a State Water-Planning Model: II. Peripheral Models of the Yellowstone Basin. Report Number 26. Montana State University, Bozeman, MT.

Boyd, D.W. and T.T. Williams. 1976. Development of a State Water-Planning Model: III. Peripheral Models of Sub-Basin 43-Q of the Yellowstone Basin. Report Number 32. Montana State University, Bozeman, MT.

Bremond, R. and R. Vuichard. 1973. Les Parametres de la Quality des Eaux. Ministere de la Protection de la Nature et de l'Environment. Secretariat Permanent pour l'Etude des Problemes de l'Eau. La Documentation Francaise.

Brown, J.W., M.R. Walsh, R.W. McCarley, A.J. Greer, Jr., and H.W. West. 1974. Models and Methods Applicable to Corps of Engineers' Urban Studies. Miscellaneous Paper H-74-78. U.S. Army, Hydraulics Laboratory, Waterways Experiment Station, Vicksburg, MS.

Buchan, G. 1975. Cybernetic Modeling for Thermal Pollution Decision-Making. In: Advances in Environmental Science and Technology. Pitts, J.N, Jr., R.L. Metcalf, and A.C. Lloyd (eds.). New York, John Wiley and Sons. 5:325-367.

Butcher, W.R. and G.W. Huetting. 1974. Model Development and Systems Analysis of the Yakima River Basin: Economic Modeling. Report Number 17G. Water Research Center, Pullman, WA.

Chamberlain, S.G. and C.B. Beckers. 1974. Quantitative Methods for Preliminary Design of Water Quality Surveillance Systems. Water Resources Bulletin. 10:199-219.

Chapra, S.C. and S. Gordimer. 1973. ES001: Verification of Model for New York Harbor. U.S. Environmental Protection Agency, Data Systems Branch, New York. NTIS Number PB-246 848.

Chen, C.W. 1970. Concepts and Utilities of Ecologic Model. ASCE Sanitary Engineering Division Journal. 96:1085-1097.

Chen, C.W., M. Lorenzen, and D.J. Smith. 1975. A Comprehensive Water Quality Ecological Model for Lake Ontario. Tetra Tech, Incorporated, Lafayette, CA.

Chen, C.W. and R.P. Shubinski. 1971. Computer Simulation of Urban Storm Water Runoff. ASCE Hydraulics Division Journal. 97:289-301.

Chen, C.W. and J.T. Wells, Jr. 1976. Boise River Ecological Modeling. In: Modeling Biochemical Processes in Aquatic Ecosystems. Canale, R.P. (ed.). Ann Arbor, Ann Arbor Science Publishers. p. 171-203.

Chow, V.T. and G. Cortes-Rivera. 1974. Application of DDDP (Discrete Differential Dynamic Programming) in Water Resources Planning. Illinois University, Water Resources Center, Urbana, IL. NTIS Number PB-231 231.

Clark, L.J. and K.D. Feigner. 1972. Mathematical Model Studies of Water Quality in the Potomac Estuary. EPA Technical Report 33. U.S. Environmental Protection Agency, Annapolis, MD. NTIS Number PB-229 797.

Claudson, R.M. 1975. The Digital Simulation of River Plankton Population Dynamics. Communications of the Association for Computing Machinery. 18:517-523.

Clymer, A.B., K.N. Braun, and R.S. Davidson. 1965. The Desirability and Feasibility of Simulating Ecological Systems. Midwestern and Central States Simulation Councils Meeting. (Unpublished).

Conference on Environmental Modeling and Simulation Proceedings. 1976. EPA-600/9-76-016. Environmental Protection Agency, Washington, DC.

Copp, H.D. and D.T. Higgins. 1974. Model Development and Systems Analysis of the Yakima River Basin: Hydraulics of Surface Water Runoff. Report Number 17B. Water Research Center, Pullman, WA.

Crawford, N.H. and A.S. Donigian, Jr. 1973. Pesticide Transport and Runoff Model for Agricultural Lands. EPA-660/2-74-013. Government Printing Office, Washington, DC. NTIS Number PB-235 723.

Crevensten, D., A. Stoddard, and G. Vajda. 1973. Water Quality Model of the Lower Fox River, Wisconsin. U.S. Environmental Protection Agency, Region V, Chicago, IL. NTIS Number PB-230 269.

Crim, R.L. 1972. A System of Mathematical Models for Water Quality Management. Technical Report Number 51. U.S. Environmental Protection Agency, Region III, Annapolis, MD.

Crim, R.L. and N.L. Lovelace. 1973. AUTO-QUAL Modeling Systems. U.S. Environmental Protection Agency, Annapolis, MD. NTIS Number PB-227 032.

Csuri, C.A. 1974. Real-Time Computer Animation. In: Proceedings of IFIP Congress 74. Rosenfeld, J.L. (ed.). New York, American Elsevier. p. 707-711.

Dee, N., J. Baker, N. Drobny, K. Duke, I. Whitman, and D. Fahringer. 1973. An Environmental Evaluation System for Water Resource Planning. Water Resources Research. 9:523-535.

Deininger, R. 1971. Models for Environmental Pollution Control. Ann Arbor, Ann Arbor Science Publishers.

Demic, J.W. 1974. Perspective Geometry and Computer Graphics: Techniques and Applications in Computer-Aided Design. In: Proceedings of the International Computing Symposium, 1973. Gunther, A., B. Levrat, and H. Lipps (eds.). New York, American Elsevier. p. 435-441.

Denes, P.B. and I.K. Gershkoff. 1974. An Interactive System for Page Layout Design. In: Proceedings of the Association for Computing Machinery, NY. p. 212-221.

DiGiano, F.A. and P.A. Mangarella. 1975. Short Course Proceedings: Applications of Stormwater Management Models. Massachusetts University, Department of Civil Engineering, Amherst, MA. NTIS Number PB-247 163.

Diskin, M.H. and A. Boneh. 1973. Determination of Optimal Kernels for Second-Order Stationary Surface Runoff Systems. Water Resources Research. 9:311-325.

Donigian, A.S., Jr. and N.H. Crawford. 1976. Modeling Pesticides and Nutrients on Agricultural Lands. EPA-600/2-76-043. U.S. Environmental Protection Agency, Athens, GA.

Dudley, N.J. 1973. Comments on "Engineering and Economic Evaluation of the Reliability of Water Supply" by E. Damelin, U. Shamir, and N. Arad. Water Resources Research. 9:771-772.

Edwards, M.D. 1974. The Processing and Storage of Water-Quality Data in the National Water Data Storage and Retrieval System. U.S. Geological Survey, Water Resources Division, Reston, VA. NTIS Number PB-236 246.

Emsellem, Y. 1973. Analyse a l'Echelle de la France des Resources en Eau et de leur Qualite ainsi que des Besoins Futurs. Service de l'Environnement et de la Protection des Consommateurs. ARLAB, Sophia-Antipolis, Valbone, France.

Engeli, M.E. 1974. A Language for 3D Graphics Applications. In: Proceedings of the International Computing Symposium, 1973. Gunther, A., B. Levrat, and H. Lipps (eds.). New York, American Elsevier. p. 459-466.

Fan, L.T. and L.E. Erickson. 1974. Development of Water Quality Models Using Spectral Analysis and Parameter Estimation Techniques. Water Resources Research Institute, Manhattan, KS. NTIS Number PB-232 986.

Ferrar, T.A. 1973. Progressive Taxation as a Policy for Water Quality Management. Water Resources Research. 9:563-568.

Ferris, J.J., N.L. Clesceri, and S.I. Auerbach. 1974. Freshwater Ecosystem Research in Water Quality Management. Environmental Science and Technology. 8:706.

Forrester, J.W. 1969. Urban Dynamics. Cambridge, MIT Press.

Fox, J.D. and D.D. Wooldridge. 1974. Model Development and Systems Analysis of the Yakima River Basin: Forest Hydrology Model. Report Number 17E. Water Research Center, Pullman, WA.

Fruh, E.G., B.R. Penumall, and R.H. Flake. 1975. Establishment of Operational Guidelines for Texas Coastal Zone Management: I. Water Quality Modeling and Management Studies for Corpus Christi Bay: A Large System Approach. Texas University, Division of Natural Resources and Environment, Austin, TX. NTIS Number PB-247 458.

Futrelle, R.P. 1974. GALATEA: Interactive Graphics for the Analysis of Moving Images. In: Proceedings of IFIP Congress 74. Rosenfeld, J.L. (ed.). New York, American Elsevier. p. 712-716.

Grantham, G.R., J.C. Schaake, Jr., and E.E. Pyatt. 1971. Water Quality Simulation Model. ASCE Journal of Sanitary Engineering. 97:569-585.

Grantham, G.R., J.C. Schaake, Jr., and E.E. Pyatt. 1973. Water Quality Simulation Model: Closure. ASCE Environmental Engineering Division Journal. 99:88-89.

Grayman, W.M., R.M. Males, W.E. Gates, and A.W. Hadder. 1975. Land-Based Modeling System for Water Quality Management Studies. ASCE Hydraulics Division Journal. 101:567-580.

Green, N.M.D. 1972. Water Quality Simulation Model. ASCE Sanitary Engineering Division Journal. 98:669-670.

Hagarman, J.A. and F.R.S. Dressler. 1975. Storm Water Management Model: Dissemination and User Assistance. National Environmental Research Center, Office of Research and Development, Cincinnati, OH.

Hamdan, A.S. and D.D. Meridith. 1974. Network Analysis of Conjunctively Operated Ground Water-Surface Water Systems. Illinois University, Water Resources Center, Urbana, IL. NTIS Number PB-231 204.

Hassett, J.P. and G.F. Lee. 1975. Modeling of Pesticides in the Aqueou Environment. In: Environmental Science Research. Haque, R. and V.H. Freed (eds.). New York, Plenum. 6:173-184.

Hobbs, N. and J.D. Britton. 1974. Computer Modeling Applications in Urban Water Planning, ASCE, New York. NTIS Number PB-233 673.

Holtan, H.N., G.J. Stilner, W.H. Henson, and N.C. Lopez. 1975. USDAHL-74: Revised Model of Watershed Hydrology. Technical Bulletin Number 1518. U.S. Agricultural Research Service, Hyattsville, MD.

Holz, T. 1971. Predictive Models of Coliforms in Streams: A Review of the State-of-the-Art. University of Washington, Water and Air Resources Division, Seattle, WA.

Hornbeck, J.W. 1973. Storm Flow from Hardwood-Forested and Cleared Watersheds in New Hampshire. Water Resources Research. 9:346-354.

House, P.W. 1974. Diogenes Revisited -- The Search for a Valid Model. Simulation. 23:117-125.

House, P.W. and G.R. Tyndall. 1975. Models and Policy Making. In: A Guide to Models in Governmental Planning and Operations. Gass, S.I. and R.L. Sisson (eds.). Potomac (MD), Sauger Books. p. 39-60.

Howrey, E.P. 1975. Econometric Models for Policy Analysis. In: A Guide to Models in Governmental Planning and Operations. Gass, S.I. and R.L. Sisson (eds.). Potomac (MD), Sauger Books. p. 375-415.

Hudetz, W.J. 1975. Sensitivity Analysis Applied to Ecosystem Models. In: Progress in Cybernetics and Systems Research. Trappl, R. and F.R. Pichler (eds.). Washington, Hemisphere Publishing. 1:213-227.

Huff, D.D. 1972. Hydrologic Simulation and the Ecological System. U.S. International Biological Program. Analyses of Ecosystems Program. Interbiome Abstracts. 2:14.

Hugg, F.A. 1970. Time Distribution Characteristics of Rainfall Rates. Water Resources Research. 6:447-454.

International Symposium on Computer Performance Modeling, Measurement and Evaluation, Proceedings. 1976. Chen, P.S. and M. Franklin (eds.). Association for Computing Machinery, New York.

Irvin, M.M. 1976. About the Cover. Computer. 9:2-3.

James, I.C., II, B.T. Bower, and N.C. Matalas. 1975. Relative Importance of Variables in Water Resources Planning. In: Selected Works in Water Resources Planning. Biswas, A.K. (ed.). International Water Resources Association, Champaign, IL. p. 221-229.

James, L.D. 1970. An Evaluation of Relationships Between Streamflow Patterns and Watershed Characteristics Through the Use of OPSET, A Self-Calibrating Version of the Stanford Watershed Model. Research Report 36. University of Kentucky, Water Resources Institute, Lexington, KY.

Jennings, M.E. and M.A. Seijo. 1973. Comments on "On Determination of BOD and Parameters in Pollution Stream Models from DO Measurements Only" by A.J. Koivo and G.R. Phillips. Water Resources Research. 9:496-497.

Kadlec, J. 1973. A Partial Annotated Bibliography of Mathematical Models in Ecology. University of Michigan, School of Natural Resources, Ann Arbor.

Kane, J., I. Vertinsky, and W. Thomson. 1973. KSIM: A Methodology for Interactive Resource Policy Simulation. Water Resources Research. 9:65-79.

Koivo, A.J. and G.R. Phillips. 1972. On Determination of BOD and Parameters in Polluted Stream Models from DO Measurement Only. Water Resources Research. 8:478-486.

Lager, J.A., R.P. Shubinski, and L.W. Russell. 1971. Development of a Simulation Model for Storm Water Management. Water Pollution Control Federation Journal. 43:2424-2435.

Lager, J.A. and W.G. Smith. 1974. Urban Stormwater Management and Technology: An Assessment. EPA-670/2-74-040. National Environmental Research Center, Office of Research and Development, Cincinnati, OH.

Langford, K.J. and J.L. McGuinness. 1976. Using a Mathematical Model to Assess the Hydrological Effects of Land-Use Change. U.S. Agricultural Research Service, North Central Region, West Beltsville, MD.

Lau, Y.L. 1972. A Review of Conceptual Models and Prediction Equations for Reaeration in Open Channel Flow. Technical Bulletin 61. Department of the Environment, Inland Waters Branch, Ottawa, Canada.

Lee, E.S. 1972. Analysis, Modeling and Forecasting of Stochastic Water Quality Systems. Water Resources Research Institute, Manhattan, KS. NTIS Number PB-226 566/567.

LeFoll, Y., G. DeMarsily, and J.P. Bordet. 1974. Analyse Multidimensionnelle des Donnees de la Campagne 1971 de l'Inventaire National du Degre de Pollution des Eaux Superficielles dans le Bassin "Seine-Normandie." ARLAB, Sophia-Antipolis, Valbone, France.

Lerseth, R. 1976. DELTA Hydrodynamic Operations Model. California Department of Water Resources, Sacramento, CA.

Lettenmaier, D.P. and S.J. Burges. 1975. Dynamic Water Quality Management Strategies. Water Pollution Control Federation Journal. 47:2809-2819.

Lindholm, O.G. 1975. A Pollutional Analysis of a Storm Overflow in a Combined Sewer System. Vatten. 31:244-252.

Linsley, R.K. 1971. A Critical Review of Currently Available Hydrologic Models for Analysis of Urban Stormwater Runoff. Hydrocomp, Incorporated, Palo Alto, CA.

Lipson, J.D. 1974. Flowgraphs and Their Generating Functions. In: Proceedings of IFIP Congress 74. Rosefeld, J.L. (ed.). New York, American Elsevier. p. 489-493.

Lombardo, P.S. 1971. A Mathematical Model of Water Quality in an Impoundment. MS Thesis. University of Washington, Seattle, WA.

Lombardo, P.S. 1972. Water Quality Simulation Model: A Discussion, ASCE Sanitary Engineering Division Journal. 98:468-470.

McCuen, R.H. 1973. Component Sensitivity: A Tool for the Analysis of Complex Water Resource Systems. Water Resources Research. 9:243-246.

McPherson, M.B. 1973. Complete Automation -- It's Still a Long Ways Off. Water and Wastes Engineering. 10:36-38.

Maguire, B., Jr. 1974. Ecosystem Simulation Through Use of Models of Subsystem Response Structures. Simulation. 23:149-158.

Mandeville, A.N. and T. O'Donnell. 1973. Introduction of Time Variance to Linear Conceptual Catchment Models. Water Resources Research. 9:298-310.

Mar, B.W. and W.R. Butcher. 1974. Model Development and Systems Analysis of the Yakima River Basin: Macro Model Simulation. Report Number 17A. Water Research Center, Pullman, WA.

Mar, B.W. 1974. Problems Encountered in Multidisciplinary Resources and Environmental Simulation Models Development. Journal of Environmental Management. 2:83-200.

Marks, D.H. 1975. Models in Water Resources. In: A Guide to Models in Governmental Planning and Operations. Gass, S.I. and R.L. Sisson (eds.). Potomac (MD), Sauger Books. p. 103-137.

Martino, E., B. Simeone, and T. Toffoli. 1973. An Automatic River Planning Operating System (ARPOS). In: Conference on Optimization Techniques. Conti, R. and A. Ruberti (eds.). New York, Springer-Verlag. 3:241-250.

Matalas, N.C. and J.R. Wallis. 1973. Eureka! It Fits a Pearson Type 3 Distribution. Water Resources Research. 9:281-289.

Mein. R.G. and C.L. Larson. 1973. Modeling Infiltration During a Steady Rain. Water Resources Research. 9:384-394.

Middlebrooks, E.J., D.H. Falkenborg, and T.E. Maloney (eds.). 1973. Modeling the Eutrophication Process. Utah State University, Water Research Laboratory, Logan, UT.

Newman, W.M. and R.F. Sproull. 1973. Principles of Interactive Computer Graphics. New York, McGraw-Hill.

O'Brien, W.T. and J.B. Hinwood. 1975. Some Components of an Ecosystem Model of Westernport Bay. Royal Society of Victoria Proceedings. 87:79-88.

O'Connor, D.J., R.V. Thomann, and D.M. DiToro. 1973. Dynamic Water Quality Forecasting and Management. EPA-660/3-73-009. U.S. Environmental Protection Agency, Office of Research and Development, Washington, DC. NTIS Number PB-225 048.

O'Neill, P.G. 1974. Towards System Models for Water Resource Management -- A Comment. Journal of Environmental Management. 2:79-82.

Ohls, J.C., P. Hutchinson, T.R. Lakshmanan, and P.D. Patterson. 1975. Models in Urban Development. In: A Guide to Models in Governmental Planning and Operations. Gass, S.I. and R.L. Sisson (eds.). Potomas (MD), Sauger Books. p. 165-200.

Park, R.A. 1968. Simulation of an Aquatic Ecosystem. Biometrics. 24:803-822.

Park, R.A. 1976a. Adaptation of Aquatic Ecosystem Model for Applied Uses. Rensselaer Polytechnic Institute, Troy, NY. Grant Proposal, RPI Number 29(77R)E145(1)).

Park, R.A. 1976b. A Model for Simulating Lake Ecosystems. Rensselaer Polytechnic Institute, Troy, NY. (Grant Proposal, NSF Number BMS 75-14168 A01).

Park, R.A. 1976c. Modeling Transport and Behavior of Pesticides and Other Toxic Organic Materials in Aquatic Environments. Rensselaer Polytechnic Institute, Troy, NY. (Grant Proposal, RPI Number 279(76R)E100(4)).

Park, R.A., R.V. O'Neill, J.A. Bloomfield, and C.S. Zahorcak. 1974. A Generalized Model for Simulating Lake Ecosystems. Simulation. 23:33-50.

Patten, B.C. (ed.). 1972. Systems Analysis and Simulation in Ecology. New York, Academic Press.

Peckam, E.H., R.A. Luken, and J.E. Mendelssohn. 1974. Supporting Government Planning of Industrial Waste-Water Treatment. In: AFIPS 1974 National Computer Conference Proceedings. 43:613-620. Montvale (NJ), AFIPS Press.

Pennington, R.H. 1974. Scientific Analysis Computational Requirements. In: Multi-Access Computing. Rosenthal, P.H. and R.K. Mish (eds.). Rochell Park (NJ), Hayden Book Company. p. 31-42.

Phillips, R.L. and S. Buda. 1976. New Graphical and Statistical Techniques for Analyzing Water Quality Data. American Chemical Society, Division of Environmental Chemistry, Preprints. 16:202-204.

Pingry, D.E. and A.B. Whinston. 1974. Application of Multigoal Water Quality Planning Model. ASCE Environmental Engineering Division Journal. 100:61-75.

Powers, W.F. and R.P. Canale. 1975. Some Applications of Optimization Techniques to Water Quality Modeling and Control. IEEE Transactions on Systems, Man and Cybernetics. SMC-5:312-321.

Prueitt, M.L. 1975. Computer Graphics. New York, Dover Publications.

Quimpo, R.F. and M. Cheng. 1974. On the Variability of Seasonal Parameters in Hydrologic Time Series. Journal of Hydrology. 23:279-287.

Radford, P.J. 1971. The Simulation Language as an Aid to Ecological Modeling. In: Mathematical Models in Ecology. Jeffers, J.N.R. (ed.). Oxford (England), Blackwell Scientific Publications. p. 277-295.

Rao, R.G.S. and A.R. Rao. 1976. Analysis of the Effects of Urbanization on Runoff Characteristics by Nonlinear Rainfall-Runoff Models. Purdue University, Water Resources Center, Lafayette, IN. NTIS Number PB-249 737.

Resource Analysis, Incorporated. 1974. Hydrologic Data Storage System: User's Manual. Resource Analysis, Incorporated, Cambridge, MA.

Resource Analysis, Incoporated. 1975. MITCAT: Catchment Simulation Model. Draft. Resource Analysis, Incorporated, Cambridge, MA.

Reumann, K. and A.P.M. Witkam. 1974. Optimizing Curve Segmentation in Computer Graphics. In: Proceedings of the International Computing Symposium, 1973. Gunther, A., B. Levrate, and H. Lipps (eds.). New York, American Elsevier. p. 467-472.

Roach, J.T. and J.W. Kelley. 1974. Application of the LUNR Inventory System for Water Resources Planning and Management in the Susquehanna River Basin. Cornell University, Water Resources and Marine Sciences Center, Ithaca, NY. NTIS Number PB-233 841.

Roesner, L.A., J.R. Monser, and D.E. Evenson. 1973. Computer Program Documentation for the Stream Quality Model QUAL-II. Water Resources Engineers, Walnut Creek, CA.

Roesner, L.A., H.N. Nichandros, R.P. Shubinski, A.D. Feldman, J.W. Abbott, and A.O. Friedman. 1974. A Model for Evaluating Runoff Quality in Metropolitan Master Planning. ASCE Urban Water Resources Research Program. NTIS Number PB-234 312.

Rust, B.W. and J.B. Mankin. 1974. Interactive Modeling of Ecosystems. Oak Ridge National Laboratories, Oak Ridge, TN. NTIS Number CONF-740703-1.

Scavia, D., J.A. Bloomfield, J.S. Fisher, J. Nagy, and R.A. Park. 1974. Documentation of CLEANX: A Generalized Model for Simulating the Open-Water Ecosystemszof Lakes. Simulation. 23:52-56.

Scavia, D. and R.A. Park. 1975. A User's Manual for the Aquatic Ecosystem Model CLEANER. Rensselaer Polytechnic Institute, Troy, NY. (Environmental Protection Agency Contract Number 68-03-2142).

Schaake, J.C., Jr., G. Leclerc, and B.M. Harley. 1973. Evaluation and Control of Urban Runoff. Preprint 2103. ASCE Annual and National Environmental Engineering Meeting.

Shirazi, M.A. and L.R. Davis. 1972. Workbook of Thermal Plume Prediction: Submerged Discharge. EPA-R2-72-005a. National Environmental Research Center, Pacific Northwest Laboratory, Corvallis, OR.

Singh, M.G. 1975. River Pollution Control. International Journal of Systems Science. 6:9-22.

Sisson, R.L. 1975. Introduction to Decision Models. In: A Guide to Models in Governmental Planning and Operations. Gass, S.I. and R.L. Sisson (eds.). Potomac (MD), Sauger Books. p. 1-37.

Slack, J.R. 1973. I Would If I Could (Self-Denial by Conditional Models). Water Resources Research. 9:247-249.

Sollins, P. 1972. A Computer Program for Modeling Ecological Systems. U.S. International Biological Program. Analysis of Ecosystems Program. Interbiome Abstracts. 2:28.

Sonnen, M.B., L.A. Roesner, and R.P. Shubinski. 1976. State-of-the-Art and Future Direction of Urban Water Management Modeling. Water Resources Engineers, Walnut Creek, CA. NTIS Number PB-249 049.

Spaulding, M.L., G.A. Brown, and F.M. White. 1974. Applying a Water Quality Model to Pollution Management: DO - BOD in Narragansett Bay. Marine Technical Report 26. Rhode Island University, Kingston, RI. NTIS Number COM-74-11592.

Splane, F.X. 1973. Comments on "Analysis of the Feasibility of Interim Water Supplies" by W.A. Hall, Y.Y. Haimes, and W.S. Butcher, Water Resources Research. 9:774.

Spolia, S.K. and S. Chander. 1974. Modeling of Surface Runoff Systems by an ARMA Model. Journal of Hydrology. 22:317-332.

Talavage, J.J. and M. Triplett. 1974. GASP IV Urban Model of Cadmium Flow. Simulation. 23:101-108.

Thomann, R.V. 1973. Effect of Longitudinal Dispersion on Dynamic Water Quality Response of Streams and Rivers. Water Resources Research. 9:355-366.

Thompson, G.T. 1974. Model Development and Systems Analysis of the Yakima River Basin: Irrigated Agricultural Water Use. Report Number 17C. Water Research Center, Pullman, WA.

Timmons, D.R., R.E. Burwell, and R.F. Holt. 1973. Nitrogen and Phosphorus Losses in Surface Runoff from Agricultural Land as Influenced by Placement of Broadcast Fertilizer. Water Resources Research. 9:658-667.

U.S. Army, Corps of Engineers, Hydrologic Engineering Center. 1973a. HEC-1: Flood Hydrographic Package; User's Manual. Generalized Computer Program 723-010. The Center, Davis, CA.

U.S. Army, Corps of Engineers, Hydrologic Engineering Center. 1973b. HEC-2: Water Surface Profiles; User's Manual. Generalized Computer Program 723-02A. The Center, Davis, CA.

U.S. Army, Corps of Engineers, Hydrologic Engineering Center. 1975a. Urban Storm Water Runoff: "STORM." Computer Program 723-S8-L2520. The Center, Davis, CA.

U.S. Army, Corps of Engineers, Hydrologic Engineering Center. 1975b. Phase I. Oconee Basin Pilot Study: Trail Creek. The Center, Davis, CA.

U.S. Army, Corps of Engineers, Hydrologic Engineering Center. 1975c. Chattahoochee River Water Quality Analysis. The Center, Davis, CA. (Preliminary Draft).

U.S. Army, Corps of Engineers, Hydrologic Engineering Center. 1976a. HEC-6: Scour and Deposition in Rivers and Reservoirs; User's Manual. Generalized Computer Program 723-G2-L2470. The Center, Davis, CA.

U.S. Army, Corps of Engineers, Hydrologic Engineering Center. 1976b. Geometric Elements from Cross Section Coordinates. Generalized Computer Program 723-G2-L745B. The Center, Davis, CA.

U.S. Army, Corps of Engineers, Hydrologic Engineering Center. 1976c. Storage, Treatment, Overflow, Runoff Model "STORM." Generalized Computer Program 723-S8-L7520, Version 2.0. The Center, Davis, CA.

U.S. Army, Corps of Engineers, Hydrologic Engineering Center. 1977. Water Quality for River-Reservoir Systems. The Center, Davis, CA. (Preliminary Draft, Chapters I-VII, X).

U.S. Department of Agriculture, Agricultural Research Service. 1975. ACTMO: An Agricultural Chemical Transport Model. ARS-H-3. Agricultural Research Service, Hyattsville, MD.

U.S. Environmental Protection Agency. 1971. Storm Water Management Model. U.S. Environmental Protection Agency, Washington, DC.

U.S. Environmental Protection Agency. 1973a. Measures for the Restoration and Enhancement of Quality of Freshwater Lakes. EPA-430/9-73-005. U.S. Environmental Protection Agency, Washington, DC.

U.S. Environmental Protection Agency. 1973b. QUAL II: Computer Program Documentation for Stream Quality Model. U.S. Environmental Protection Agency, Systems Development Branch, Washington, DC. (EPA Contract Number 68-01-0739).

Vincens, G.J., B.M. Harley, and J.C. Schaake, Jr. 1975. FLOW2D: A Two-Dimensional Flow Model for Flood Plains and Estuaries. ASCE Symposium on Modeling Techniques Proceedings. p. 1487-1504.

Vuilleumier, G. and M. Sarret. 1974. Finger Input to a Small Graphic System. In: Proceedings of the International Computing Symposium, 1973. Gunther, A., B. Levrat, and H. Lipps (eds.). New York, American Elsevier. p. 473-480.

Ward, R.C. and D.H. Vanderholm. 1973. Cost-Effectiveness Methodologies for Data Acquisition in Water Quality Management. Water Resources Research. 9:536-545.

Watson, K.K. and S.J. Lees. 1975. Simulation of the Rainfall Runoff Process Using a Hysteretic Infiltration Re-Distribution Model. Australian Journal of Soil Research. 13:133-140.

Watt, W.E. and C.H.R. Kidd. 1975. QUURM -- A Realistic Urban Runoff Model. Journal of Hydrology. 27:225-235.

Webb, K.W., F.L. Spielberg, and P.S. Loubal. 1975. Models in Transportation. In: A Guide to Models in Governmental Planning and Operations. Gass, S.I. and R.L. Sisson (eds.). Potomac (MD), Sauger Books. p. 201-230.

Whinston, A.B. 1975. Implementation of a NPDES Data Management System. Purdue University, Water Resources Research Center, Lafayette, IN. NTIS Number PB-247 112.

Willey, R.G. 1975. Water Quality Evaluation of Aquatic System. Technical Paper 38. U.S. Army, Corps of Engineers, Hydrologic Engineering Center, Davis, CA.

Winn, C.B. 1972. The Use of Hydrological Simulation and Remote Sensing in an Integrated Program for Water Resource Systems. Simulation. 19:13-18.

Wnek, W.J. and E.G. Fochtman. 1972. Mathematical Model for Fate of Pollutants in Near-Shore Waters. Environmental Science and Technology. 6:331-337.

Yearsley, J. 1975. Evaluation of Lake Milner Water Quality Model. U.S. Environmental Protection Agency, Region X, Seattle, WA. NTIS Number PB-247 651.

Appendix A

BIBLIOGRAPHICAL SOURCES

A custom search was conducted to provide a bibliography to support the "Feasibility Study on Executive Program Development for Basin Ecosystems Modeling" using the following information centers:

Computing Reviews
Association for Computing Machinery
New York, NY

Engineering Index
Engineering Index, Incorporated
New York, NY

The Environment Index
Environment Information Center
New York, NY

Eutrophication: A Bimonthly Summary of Current Literature
Water Resources Information Program
University of Wisconsin
Madison, WI

Government Reports Announcement Index
National Technical Information Service
Springfield, VA

International Abstracts in Operation Research
International Federation of Operational Research Societies
Amsterdam, The Netherlands

Selected Water Resources Abstracts
Water Resources Scientific Information Center
Washington, DC

The following indexes were used to follow up likely citations:

Nuclear Science Abstracts
U.S. Atomic Energy Commission
Technical Information Service Extension
Oak Ridge, TN

Science Citation Index
Institute for Scientific Information
Philadelphia, PA

In addition, the following bibliographical data bases were queried for pertinent citations:

Datrix II
University Microfilms
Ann Arbor, MI

Smithsonian Scientific Information Exchange
Smithsonian Institute
Washington, DC

BIOSIS
State University of New York Biomedical Network
Albany, NY

Appendix B

SAMPLE OF SOLICITING LETTER

The content of this letter and its abstract were sent to the 281 recipients listed in Appendix C.

LETTER

July , 1976

Dear :

I am presently contacting leading scientists who might be interested in the development of an executive package for the Environmental Protection Agency.

I have recently been awarded a grant with EPA entitled "Feasibility Study on the Executive Program Development for Basin Ecosystems Modeling." Its objective is to determine the cost and time required to develop a computer software package which could link various water quality and watershed runoff models in a systematic fashion. In addition to automatic linkage, the software developed would provide efficient data handling and parameter estimation capabilities.

If you are interested, please contact me at the following numbers:

Office: 518/564-2201
Department secretary: 518-564-2116

I am also enclosing a brief abstract of the EPA feasibility study.

Sincerely yours,

Hubert Bouver
Assistant Professor
of Computer Science

ABSTRACT

The objective of this grant proposal is to conduct a comprehensive investigation to determine, based on state-of-the-art environmental systems models, the feasibility of developing and implementing a complete executive program to interface automatically various basin water quality models for use by relatively inexperienced modelers. Specifically, in addition to determining the technical feasibility of development, an estimate of the cost of development will be made as well as estimate of the length of time required to carry out such an undertaking.

Ultimately this executive program should have the capability to integrate various water quality, point source and nonpoint source models and to simulate and analyze the consequences of implementing land use alternatives and pollution control strategies. The executive would calculate all pertinent parameters and coupling efforts so that socio-economics, energy and economic constraints can be considered in a coherent manner.

Appendix C

LIST OF PRIMARY CONTACTS

(Listed in alphabetical order by state and institutions)

This list comprises the original attempt to contact and solicit leading scientists who wanted to participate in this feasibility study on the development of the executive package. This list was primarily compiled through an extensive library search. A sample letter, which may be found in Appendix B, was sent to all 281 recipients listed.

ALABAMA

Auburn University
Dr. E.W. Shell
International Center for Aquaculture
Auburn 36830

Auburn University
Water Resources Research Institute
Auburn 36830

Lockheed Aircraft Corporation
Environmental Research Branch
Huntsville 35807

University of Alabama
Center for Environmental and Energy Studies
P.O. Box 1247
Huntsville 35807

ALASKA

University of Alaska
Dr. Robert F. Carlson
Institute of Water Resources
Fairbanks 99701

ARIZONA

Arizona State University
Forest Hydrology Laboratory
Tempe 85281

University of Arizona
Agriculture Experimental Station
Tucson 85721

University of Arizona
Water Resources Research Center
102 Old Psychology Building
Tucson 85721

CALIFORNIA

ABAG
Dr. Yoram Litwin
Hotel Claremont
Berkeley 94705

Berkeley University
Professor P.H. McGauhey
Sanitary Engineering Research Laboratory
Berkeley 94720

Berkeley University
Dr. Robert Selick
Professor of Civil Engineering
Berkeley 94720

Boyle Engineering Corporation
1501 Quail
Newport Beach 92660

California Department of Water Resources
Dr. Richard J. Lerseth
Delta Branch, Environmental Studies
Sacramento 95814

California Institute of Technology
Dr. James J. Morgan
Keck Laboratory
Pasadena 91125

California Institute of Technology
U.S. NASA Jet Propulsion Laboratory
1201 East California Boulevard
Pasadena 91109

Compass Systems, Incorporated
Mr. R. Bayer
4640 Jewell Street; Apartment 204
San Diego 92109

Environmental Dynamics, Incorporated
Dr. John A. Dracup, President
1609 Westwood Boulevard; suite 202/3
Los Angeles 90024

Hydrocomp, Incorporated
Dr. Norman H. Crawford
1502 Page Mill Road
Palo Alto 94025

Hydrocomp, Incorporated
Mr. Jean Jacques Heler
Senior Systems Designer
1502 Page Mill Road
Palo Alto 94304

Hydrologic Engineering Center
U.S. Army, Corps of Engineers
Dr. Jess Abbott
Research Hydraulic Engineer
609 Second Street
Davis 95616

Hydrologic Engineering Center
U.S. Army, Corps of Engineers
Dr. Darryl W. David
609 Second Street
Davis 95616

Hydrologic Engineering Center
U.S. Army, Corps of Engineers
Dr. Jerry R.G. Willey
609 Second Street
Davis 95616

HydroScience, Incorporated
Dr. Donald J. O'Connor, Director
2815 Mitchell Drive
Walnut Creek 94598

IBM Corporation
Dr. Hilary Stinton
Montere Cottle Road
San Jose 95125

Palo Alto Scientific Center - IBM
Dr. Baxter Armstrong
1501 California Street
Palo Alto 94302

Pomona College
Dr. Albert J. Leo
Medicinal Chemistry Project
Claremont 91711

Resource Management Associates
Dr. Jerry Orlob
3700 Mount Diablo Boulevard
Walnut Creek 94596

Stanford Research Institute
Dr. Shonh Lee
333 Ravenswood Avenue
Menlo Park 94025

Stanford Research Institute
Dr. William R. Mabey
333 Ravenswood Avenue
Menlo Park 94025

Stanford Research Institute
Hopkins Marine Station
Pacific Grove 93950

Stanford Research Institute
Hydraulics Laboratory
Department of Civil Engineering
Stanford 94305

Systems Control, Incorporated
1801 Page Mill Road
Palo Alto 94302

TRW, Incorporated
1 Space Park
Redondo Beach 90278

Tetra Tech, Incorporated
Dr. Carl W. Chen
3700 Mount Diablo Boulevard
Lafayette 94549

Tetra Tech, Incorporated
630 North Rosemead Boulevard
Pasadena 91107

University of California
Dr. Donald G. Crosby
Davis 95616

University of California
Professor C.S. Foote
Department of Chemistry
Los Angeles 90024

University of California
Professor David Jenkins
Sanitary Engineering Research
Laboratory
1301 South 46th Street
Richmond 94804

University of California
Dr. Ray Krone
Civil Engineering
Davis 95616

University of California
Dr. G. Taborsky
Marine Laboratory
Santa Barbara 93106

University of California
Dr. Kenneth E.F. Watt
Environmental Systems Group
Department of Zoology
Davis 95616

University of California
Dr. Kent Wilson
Department of Chemistry
La Jolla 92037

University of California
California Agricultural Experiment
Station
2200 University Avenue
Berkeley 94720

University of California
Dr. Hugo Fisher
Hydraulic Laboratory
O'Brian Hall
Berkeley 94720

University of California
Hydraulic Laboratory for Oceanography
P.O. Box 1529
La Jolla 92037

University of California
Lawrence Livermore Laboratory
P.O. Box 808
Livermore 94550

University of California
School of Agriculture
Riverside 92502

University of California
Dr. Herb Snyder
Water Resources Center
Davis 95616

U.S. Department of the Interior
Geological Survey
345 Middlefield Road
Menlo Park 94025

Water Resources Engineers, Incorporated
Dr. Dan Envanson, Vice-President
710 South Broadway
Walnut Creek 94596

Water Resources Engineers,
Incorporated
Dr. Larry Roesner
710 South Broadway
Walnut Creek 94596

Water Resources Engineers,
Incorporated
Dr. H.N. Shubinski
710 South Broadway
Walnut Creek 94596

COLORADO

Colorado State University
Dr. C. Byron Winn
Computer Science Department
Fort Collins 80521

Colorado State University
Water Intelligence Systems Study
Civil Engineering Department
Fort Collins 80521

National Oceanic and Atmospheric
Administration
Environmental Research Laboratory
3100 Marine Avenue
Boulder 80302

U.S. Department of the Interior
Geological Survey
Box 25046
Denver 80225

CONNECTICUT

Environmental Protection Research
Institute
24 Central Avenue
Waterbury 06702

University of Connecticut
Dr. Peter Dehlinger
Marine Sciences Institute
Avery Point
Groton 06340

DISTRICT OF COLUMBIA

American Iron and Steel Institute
Dr. John P. Roche
1000 Sixteenth Street, North-West
Washington 20036

American Petroleum Institute
Dr. Frank N. Ikard
1801 K Street, North-West
Washington 20006

Delaware River Basin Commission
Office of the U.S. Commissioner
Room 2347
Department of the Interior Building
18th and C Streets, North-West
Washington 20240

Environmental Protection Agency
Environmental Systems Modeling Branch
401 M Street, South-West
Washington 20460

Naval Research Laboratory
Ms. Constance Patouillet
4555 Overlook Avenue, South-West
Washington 20375

U.S. Navy
Computation and Mathematics Department
Washington 20034

Water Pollution Control Federation
Dr. Robert A. Canham
3900 Wisconsin Avenue, North-West
Washington 20016

FLORIDA

Connell-Metcalf and Eddy, Incorporated
1320 South Dixie Highway
Coral Gables 33134

Consulting Engineers
Mr. William Bishop
317 East Virginia Street
Tallahassee 32302

State University of Florida
Graduate School
Saint Petersburg 33730

State University of Florida
School of Agriculture
Gainesville 32601

State University of Florida
School of Arts and Sciences
205 Wildwood Drive
Tallahassee 32306

State University of Florida
School of Engineering
204 Tigert Hall
Gainesville 32601

University of Florida
Dr. J.F. Darby
Agriculture Research and Education Center
P.O. Box 909
Sanford 32771

University of Florida
Dr. James M. Davidson
Soil Science Department
2169 McCarty Hall
Gainesville 32611

University of Florida
Dr. Alex E.S. Green
221 SSRB
Gainesville 32611

U.S. Department of the Interior
Geological Survey
Miami 33130

U.S. Department of the Interior
Geological Survey
Tallahassee 32304

U.S. Department of the Interior
Geological Survey
Tampa 33602

U.S. Department of the Interior
Geological Survey
Winter Park 32789

GEORGIA

U.S. Department of the Interior
Geological Survey
Atlanta 30309

IDAHO

University of Idaho
Engineering Experiment Station
Moscow 83843

ILLINOIS

Argonne National Laboratory
Dr. David N. Edgington
9700 South Case Avenue
Argonne 60439

Illinois Institute of Technology
Dr. E.H. Schulz
IIT Research Institute
10 West 35th Street
Chicago 60616

University of Chicago
School of Social Science
5081 South Ellis Avenue
Chicago 60637

University of Illinois
Civil Engineering Research Laboratories
1114 Civil Engineering Building
Urbana 61801

University of Illinois
Hydrosystems Laboratory
Department of Civil Engineering
Urbana 61801

INDIANA

Indiana University
Professor Rovert V. Ruke
Water Resources Research Center
1005 East 10th Street
Bloomington 47401

Purdue University
Dr. Robert Bonczek, Assistant Professor
Department of Management and Computer Science
Krannert Building
West Lafayette 47907

Purdue University
Dr. A.B. Whinston
Department of Management
Krannert Building
West Lafayette 47907

Purdue University
Water Resources Research Center
West Lafayette 47906

IOWA

Iowa Department of Environmental Quality
Dr. Dennis Arthur Quan
3920 Delaware Avenue
P.O. Box 3326
Des Moines 50316

Iowa State University of Science and Technology
Agriculture Experiment Station
Beardshear Hall
Ames 50010

University of Iowa
Dr. Tom Croley
Institute of Hydraulic Research
Iowa City 52240

University of Iowa
Dr. W.J. Hausler
State Hygienic Laboratory
Medical Laboratories Building
Iowa City 52242

KANSAS

Kansas State University
Mr. J.K. Koelliker
School of Engineering
Anderson Hall
Manhattan 66502

University of Kansas
Water Resources Research Institute
Lawrence 66044

KENTUCKY

University of Kentucky
Dr. Robert B. Grieves
Kentucky Water Resources Research Institute
University Station
Lexington 40506

LOUISIANA

Louisiana State University
Dr. Philip W. West
Institute for Environmental Science
Coates Chemical Laboratories
Baton Rouge 70803

Louisiana Technology University
Division of Engineering Research
P.O. Box 4875, Tech Station
Ruston 71270

Tulane University
Dr. James Mason
Environmental Health Sciences Research Laboratory
F. Edward Hebert Research Center
New Orleans 70118

MAINE

University of Maine
Dr. M. Wayne Hall
Water Resources Research Center
Auburn Hall
Bangor 04401

MARYLAND

Annapolis Field Office
U.S. Environmental Protection Agency
Annapolis Science Center
Annapolis 21401

Johns Hopkins University
Mr. D.W. Pritchard
Chesapeake Bay Institute
Box 32A, RFD #3
Back Creek and Edgewood Road
Annapolis 21218

Hittman Corporation
9190 Red Branch Road
Columbia 21045

National Oceanic and Atmospheric
Administration
Washington Science Center
Rockville 20850

University of Maryland
Dr. James E. Ayars
College of Agriculture
Department of Agricultural
Engineering
College Park 20742

University of Maryland
Dr. R.L. Green
Water Resources Research Center
Shriver Laboratory
College Park 20742

University of Maryland
Dr. Lamar Harris, Chairman
Agriculture Engineering
Shriver Laboratory
College Park 20742

University of Maryland
Dr. H.N. Holtan, Lecturer
Agriculture Engineering Department
College Park 20742

University of Maryland
School of Engineering
College Park 20740

U.S. Department of Agriculture
Agricultural Research Center
Beltsville 20765

U.S. Department of Commerce
Engineering Development Laboratory
6001 Executive Boulevard
Rockville 20852

MASSACHUSETTS

Bolt, Beranete and Newman,
Incorporated
50 Moulton Street
Cambridge 02138

Clark University
Dr. Harry F. Schwarz, Professor
Environmental Affairs
Worcester 01601

Harvard University
Dr. J. Carrell Morris
Division of Engineering and Applied
Physics
127 Pierce Hall
Cambridge 02138

Harvard University
School of Engineering
Cambridge Station
Cambridge 02138

Massachusetts Institute of Technology
Dr. David H. Marks, Professor
Ralph M. Parsons Laboratory for Water
Resources and Hydrodynamics
Department of Civil Engineering
Building 48-305
Cambridge 02139

Massachusetts Institute of Technology
Dr. Nicolas P. Negroponte
Department of Computer Graphics
Cambridge 02139

Massachusetts Institute of Technology
Dr. Keith Stolzenback
Ralph M. Parsons Laboratory for Water Resources and Hydrodynamics
Department of Civil Engineering
Building 48-305
Cambridge 02139

Massachusetts Institute of Technology
Division of Sponsored Research
Cambridge 02139

Massachusetts Institute of Technology
School of Engineering
Cambridge 02139

Meta Systems, Incorporated
10 Holworthy Street
Cambridge 02138

Mitre Corporation
Burlington Road
Bedford 01730

Resource Analysis, Incorporated
Director
Cambridge 92139

Resource Analysis, Incorporated
Dr. Brendan M. Harley, President
Hydrology - Water Resource Systems - Public Systems
Cambridge 02138

Resource Analysis, Incorporated
Dr. Guillermo J. Vincens
Hydrology - Water Resource Systems - Public Systems
Cambridge 02138

University of Massachusetts
Dr. Warren Litsky
Department of Environmental Sciences
Amherst 01002

U.S. Department of the Interior
Geological Survey
150 Causeway Street
Boston 02203

Urban Water Resources Research Program
American Society of Civil Engineers
23 Watson Street
Marblehead 01945

MICHIGAN

Cranbrook Institute of Science
500 Lone Pine Road
Bloomfield Hills 48013

Michigan State University
Dr. Bill Cooper
Department of Zoology
Lansing 48824

University of Michigan
Mr. R.H. Kadlec
School of Engineering
Ann Arbor 48106

U.S. Department of the Interior
Geological Survey
Okemos 48864

Wayne State University
Detroit 48202

MINNESOTA

University of Minnesota
School of Forestry
105 Morrill Hall
Minneapolis 55101

University of Minnesota
USDA Street, Anthony Falls Laboratory
Mississippi River and 3rd Avenue
Minneapolis 55414

U.S. Department of the Interior
Geological Survey
Minneapolis 55414

MISSISSIPPI

Corps of Engineers, U.S. Army
Dr. Rex Eley
Waterways Experiment Station
Environmental Laboratory
P.O. Box 631
Vicksburg 39180

Corps of Engineers, U.S. Army
Mr. Donald L. Robey
Waterways Experiment Station
P.O. Box 631
Vicksburg 39180

Corps of Engineers, U.S. Army
Mr. Thomas Walski
Waterways Experiment Station
P.O. Box 631
Vicksburg 39180

University of Mississippi
Forest Hydrology Laboratory
P.O. Box 947
Oxford 38655

U.S. Department of the Interior
Geological Survey
Bay Saint Louis 39520

MISSOURI

Midwest Research Institute
425 Volker Boulevard
Kansas 64110

University of Missouri
Dr. Sotirios G. Grigoropoulos
Environmental Research Center
Rolla 65401

University of Missouri
Dr. Elmer R. Kiehl
Missouri Agriculture Experiment
Station
2-69 Agriculture Building
Columbia 65201

MONTANA

Montana State University
Dr. Donald W. Boyd, Associate
Professor
Department of Industrial Engineering
and Computer Sciences
Bozeman 50715

Montana State University
Dr. David G. Stuart, Director
Water Resources Research Center
349 Reid Hall
Bozeman 59715

U.S. Department of the Interior
Geological Survey
Billings 59103

NEBRASKA

University of Nebraska
Agriculture Experiment Station
Lincoln 68508

University of Nebraska
School of Engineering
Lincoln 68508

NEVADA

National Environmental Research
P.O. Box 15027
Las Vegas 89114

University of Nevada
Desert Research Institute
Reno 89507

NEW HAMPSHIRE

University of New Hampshire
Professor Gordon L. Byers
Water Resources Research Center
James Hall
Durham 03824

University of New Hampshire
Institute of Natural and
Environmental Resources
Pettee Hall
Durham 03824

NEW JERSEY

Clinton Bogert Associates
2125 Center Avenue
Fort Lee 07024

Fairleigh Dickinson University
Dr. Wallace Arthur
Science and Engineering Research
Center
1000 River Road
Teaneck 07666

HydroScience, Incorporated
Director
363 Old Hook Road
Westwood 07675

Rutgers University
Mr. William Whipple
Water Resources Research Institute
Cook College Campus
New Brunswick 08903

Princeton University
Princeton 08540

NEW MEXICO

Computer Graphics
Dr. Melvin L. Prueitt, President
Los Alamos Scientific Laboratory
Los Alamos 97544

New Mexico State University
Agriculture Experiment Station
University Park
Las Cruces 88070

NEW YORK

Brookhaven National Laboratories
Computer Center
Upton, Long Island 11973

Clarkson College of Technology
Mr. Albert Balugian
Division Research
Potsdam 13676

Cornell University
Professor D.P. Loucks
Civil Engineering
Ithaca 14850

Cornell Universith
Dr. Carl Schofield
Ithaca 14850

Cornell University
Professor Leonard B. Sworsky
Environmental Civil Engineering
302 Hillister Hall
Ithaca 14850

City University of New York
Dr. Eric Posnentier
Institute of Marine and Atmospheric
Science
675 West 252nd Street
Bronx 10471

Grumman Ecosystems Corporation
111-T Stewart Avenue
Bethpage 11714

Halcon Computer Technology,
Incorporated
2 Pennsylvania Plaza
New York 10016

IBM
Mr. Robert Morris
Armonk 10504

IBM Research Center
Dr. Samuel Smart
Yorktown Heights 10598

International Ozone Institute
Dr. Myron E. Browning, Managing Director
Skytop Merrill Lane
Syracuse 13210

Manhattan College
School of Engineering
4513 Manhattan College Parkway
Bronx 10471

NASA Space Study
Dr. Jerome Spar
2880 Broadway Avenue
New York 10031

New York Ocean Science Laboratory
Dr. Hollman
P.O. Drawer EE
Mantauk 11954

Rensselaer Polytechnic Institute
Dr. Richard A. Park
Freshwater Institute and Department of Geology
Troy 12181

Rensselaer Polytechnic Institute
Office of Research and Sponsored Programs
Troy 12181

Rensselaer Polytechnic Institute
Office of Research and Sponsored Programs
Computer Center
Troy 12181

Rensselaer Polytechnic Institute
Soil Mechanics Laboratory
Eighth Street
Troy 12181

Syracuse Research Corporation
Dr. Lionel H. Naum, Director
Merrill Lane
Syracuse 13210

State University of New York
Dr. Peter Brown
Lake Ontario Environmental Laboratory
Oswego 13126

State University of New York
Dr. Donald C. McNaught
Department of Biological Sciences
Albany 12203

State University of New York
Dr. Robert A. Sweeney, Director
1300 Elmwood Avenue
Great Lakes Laboratory
Buffalo 14222

State University of New York
College at Fredonia
Lake Erie Environmental Studies Group
Fredonia 14063

NORTH CAROLINA

National Environmental Research Center
University Park
Research Triangle Park 27711

North Carolina State University
Dr. Irving S. Goldstein, Head
Department of Wood and Paper Science
Box 5488
Raleigh 27607

North Carolina State University
Dr. R.G. Hitchings, Professor
School of Forest Resources
Robertson Pulp and Paper Laboratory
Box 5516
Raleigh 27607

North Carolina State University
Dr. Frank Humenik
Biological and Agricultural Engineering Department
Raleigh 27607

U.S. Department of the Interior
Geological Survey
Raleigh 27607

NORTH DAKOTA

North Dakota State University
Dr. Dale O. Anderson
North Dakota Water Resources
Research Institute
State University Station
Fargo 58102

University of North Dakota
Professor Joe K. Neel
University Biological Station
Grand Forks 58201

OHIO

Battelle Memorial Institute
Dr. Sherwood L. Fawcett
505 King Avenue
Columbus 43201

Battelle Memorial Institute
Dr. Ted Thomas
505 King Avenue
Columbus 43201

Case Western Reserve University
Dr. Peter Melnyk
Chemical Engineering Department
Cleveland 44106

Case Western Reserve University
School of Arts
2040 Adelbert Road
Cleveland 44106

Cleveland State University
Dr. Maryl Galloway
Department of Chemical Engineering
Cleveland 44115

Kent State University
Dr. E.P. Wenninger, Director
Environment Systems
Kent 44242

National Environmental Research
Center
Systems Modeling Branch
Cincinnati 45268

Ohio State University
Dr. Edwin E. Smith
Chemical Engineering Research Unit
140 West 19th Avenue
Columbus 43210

Ohio State University
Dr. Robert Steifel, Director
Water Resources Center
1791 Neil Avenue
Columbus 43210

Ohio State University
Engineering Experiment Station
2070 Neil Avenue
Columbus 43210

University of Cincinnati
Clifton Avenue
Cincinnati 45221

U.S. Army Corps of Engineers
Federal Office Building
550 Main Street
Cincinnati 45202

W.E. Gates and Associates,
Incorporated
Dr. Richard M. Males
Cincinnati 45268

Youngstown State University
Dr. Michael Householder, Chairman
Department of Chemical Engineering
Youngstown 44503

OKLAHOMA

Oklahoma State University
Dr. Troy C. Dorris
Reservoir Research Center
Stillwater 74074

Oklahoma State University
Agriculture Experiment Station
107 Whitehurst Hall
Stillwater 74074

OREGON

Environmental Protection Agency
Dr. Mustafa Shirazi
Corvallis 97330

Oregon State University
Dr. A.F. Bartsch
National Environmental Research Center
200 South-West 35th Street
Corvallis 97331

Oregon State University
Dr. William Buckley
Water Resources Research Institute
Covell Hall
Corvallis 97331

Oregon State University
Dr. Virgin H. Freed
Department of Agricultural Chemistry
Corvallis 97331

Oregon State University
Dr. Charles E. Warren
Pacific Fisheries and Water Pollution Laboratory
315 Extension Hall
Corvallis 97331

Oregon State University
Oregon Agricultural Experiment Station
Corvallis 97331

PENNSYLVANIA

Carnegie-Mellon University
Dr. Robert W. Dunlap
Environmental Studies Institute
Schenley Park
Pittsburgh 15213

Drexel University
Dr. I. Suffet
School of Science
32nd and Chestnut Streets
Philadelphia 19104

Drexel University
School of Engineering
32nd and Chestnut Streets
Philadelphia 19104

Pennsylvania State University
Dr. Robert L. Butler
Pennsylvania Cooperative Fishery Unit
208 Life Science Building
University Park 16802

Pennsylvania State University
Professor Paul Ebaugh
Engineering Research Program
105 Hammond Building
University Park 16802

Pennsylvania State University
Institute for Research on Land and Water Resources
108 Research Building A
University Park 16802

Pennsylvania State University
USDA Soil and Water Conservation Division
201 Shields Building
University Park 16802

University City Science Center Institute
3568 Market Avenue
Philadelphia 19104

U.S. Department of the Interior
Geological Survey
Harrisburg 17104

RHODE ISLAND

Brown University
Dr. John O. Edwards
Department of Chemistry
Providence 02912

Raytheon Company
1847 West Main Road
Portsmouth 02871

University of Rhode Island
Dr. A. Ralph Thompson
Water Resources Center
213 Crawford Hall
Kingston 02881

SOUTH CAROLINA

Clemson University
Water Resources Research Institute
Clemson 29631

Dupont de Nemours and Company
Mr. D.W. Hayes
Aiken 29801

U.S. Department of the Interior
Geological Survey
Columbia 29204

SOUTH DAKOTA

South Dakota State University
Dr. Donald C. Hales
Cooperative Fishery Unit
Wildlife Building
Brookings 57006

South Dakota State University
Mr. Den J.O. Storry
Engineering Experiment Station
Brookings 57006

South Dakota State University
Dr. John L. Wiersma
Water Resources Institute
Brookings 57006

South Dakota State University
Remote Sensing Institute
Brookings 57006

TENNESSEE

Oak Ridge National Laboratory
Dr. W.R. Emanuel
Environmental Sciences Division
P.O. Box X
Oak Ridge 37830

Oak Ridge National Laboratory
Dr. Robert A. Goldstein
Environmental Sciences Division
P.O. Box X, Building 2001
Oak Ridge 37830

Oak Ridge National Laboratory
Dr. Dale D. Huff
Environmental Sciences Division
P.O. Box X
Oak Ridge 37830

Oak Ridge National Laboratory
Dr. D.C. Parzyck
Environmental Sciences Division
P.O. Box X
Oak Ridge 37830

Oak Ridge National Laboratory
Dr. M.R. Patterson
Environmental Sciences Division
P.O. Box X
Oak Ridge 37830

Oak Ridge National Laboratory
Dr. John Shepard
Environmental Sciences Division
P.O. Box X
Oak Ridge 37830

Oak Ridge National Laboratory
Dr. H.H. Shugart
Environmental Sciences Division
P.O. Box X, Building 3017
Oak Ridge 37830

Oak Ridge National Laboratory
Environmental Research, Director
Oak Ridge 37830

Oak Ridge National Laboratory
P.O. Box X
Oak Ridge 37831

University of Tennessee
Professor Floyd C. Larson
Water Resources Research Center
Knoxville 37916

Vanderbilt University
Professor Barry A. Benedict
Water Resources Scientific
Information Center
Nashville 57203

TEXAS

North Texas State University
Dr. W.H. Glaze
Institute for Environmental Studies
Box 5057, N.T. Station
Denton 76203

Texas A&M University
Dr. J.R. Runkles
Water Resources Institute
College Station 77843

Texas A&M University
School of Engineering
P.O. Box FE 44
College Station 77843

Texas Instruments, Incorporated
Dr. Robert Stratton, Director
Central Research Laboratories
P.O. Box 5936
Dallas 75222

Texas Instruments, Incorporated
Environmental Division
P.O. Box 5474
Dallas 75222

Texas Tech University
Water Resources Center
Lubbock 79409

University of Texas
Dr. Bassett Maguire, Jr.
Department of Zoology
Austin 78712

University of Texas
School of Engineering
200 West 21st Street
Austin 78712

UTAH

Utah State University
School of Agriculture
Agricultural Science Building,
Room 223A
Logan 84321

Utah State University
Utah Center for Water Resources
Research, UMC 82
Logan 84322

VERMONT

Aquatec, Incorporated
1025 Airport Drive
Burlington 05401

VIRGINIA

Chase, Rosen and Wallace
901 North Washington Street
Alexandria 22313

Virginia Polytechnic Institute and
State University
Dr. Charles W. Steger
College of Architecture and Urban
Systems
Blacksburg 24061

Virginia Polytechnic Institute and
State University
School of Engineering
Burruss Hall
Blacksburg 24601

U.S. Department of the Interior
Geological Survey
12202 Sunrise Valley Drive
Herndon 22092

U.S. Department of the Interior
Geological Survey
Dr. U.E. McKelney, Director
Reston 22092

WASHINGTON

Battelle-Northwest
Dr. Ronald C. Routson
P.O. Box 999
Richland 99352

University of Washington
Fisheries Research Institute
Seattle 98195

University of Washington
School of Engineering
206 Guggenheim Hall
Seattle 98105

Washington State University
School of Agriculture
Pullman 99163

Washington State University
School of Science
Pullman 99163

Washington State University
State of Washington Water Resources
Center
Pullman 99163

WISCONSIN

Institute of Environmental Studies
Dr. Peter Weiler
WARF Building, Room 511
610 North Walnut Street
Madison 53706

Milwaukee School of Engineering
Dr. Robert W. Braun
Environmental and Water Resources
Laboratory
1025 North Milwaukee Street
Milwaukee 53201

University of Wisconsin
Dr. John A. Hoopes, Professor
Department of Civil Engineering
Madison 53706

University of Wisconsin
Dr. Byron H. Shaw
School of Natural Resources
Stevens Point 54481

University of Wisconsin
Dr. Roger A. Simons
Science and Environmental Department
Green Bay 54302

University of Wisconsin
Water Resources Center
Agriculture Hall
Madison 53706

WYOMING

University of Wyoming
Mr. R.D. Kerr
Water Resources Research Institute
P.O. Box 3038
University Station
Laramie 82070

CANADA

Bedford Institute of Oceanography
Dr. K. Kranck
Atlantic Oceanographic Laboratory
Box 1006
Dartmouth, Nova Scotia B2Y 4A2

Mr. James F. MacLaren
435 McNicoll Avenue
Willowdale, Ontario

McMaster University
Dr. K.L. Murphy
Wastewater Research Group
Department of Chemical Engineering
Hamilton, Ontario L8S 4L7

University of British Columbia
Dr. C.S. Holling
Resource Science Centre
Vancouver 8, British Columbia

University of British Columbia
Dr. Laurie Parker
Department of Computer Science
Vancouver 8, British Columbia

University of Manitoba
Dr. G.H. Lawler
Freshwater Institute
501 University Crescent
Winnipeg, Manitoba R3T 2N6

University of Saskatchewan
Dr. F.M. Atton
Saskatchewan Fisheries Laboratory
122 S.R.C. Building
30 Campus Drive
Saskatoon, Saskatchewan

University of Toronto
Dr. D. Mackay
Department of Chemistry Engineering
and Applied Chemistry
Toronto, Ontario M5S 1A4

FRANCE

ARLAB
Dr. Yves Emsellem, President
Directeur General
Service de l'Environnement et de la
Protection des Consommateurs
Sophia-Antipolis, Valbone 06560

ARLAB
Dr. Jean Pierre Bordet
Laboratoire d'Hydrogeologie
Sophia-Antipolis, Valbone 06560

Appendix D

LIST OF RESPONDENTS

(Listed in alphabetical order by state and institution)

This list is made of 68 respondents to the first letter which solicited leaders in the field of water quality modeling and computer software analysis.

CALIFORNIA

Berkeley University
Dr. Robert Selick, Professor of
Civil Engineering
Berkeley 94720

Compass Systems, Incorporated
Dr. Roger A. Bauer, President
4640 Jewell Street, Number 204
San Diego 92109

Department of Water Resources
Mr. Richard J. Lerseth
Delta Branch, Environmental Studies
Sacramento 95814

Environmental Dynamics, Incorporated
Dr. John A. Dracup, President
1609 Westwood Boulevard, suite 202/3
Los Angeles 90024

Hydrocomp, Incorporated
Dr. Norman H. Crawford, President
1502 Page Mill Road
Palo Alto 94304

Hydrocomp, Incorporated
Mr. Jean Jacques Heler, Senior
Systems Designer
1502 Page Mill Road
Palo Alto 94304

Hydrologic Engineering Center
Corps of Engineers, U.S. Army
Dr. Jess Abbott, Research
Hydraulic Engineer
609 Second Street
Davis 95616

Hydrologic Engineering Center
Corps of Engineers, U.S. Army
Dr. Darryl W. David
609 Second Street
Davis 95616

Hydrologic Engineering Center
Corps of Engineers, U.S. Army
Dr. Jerry R.G. Willey
609 Second Street
Davis 95616

IBM Corporation
Dr. Hilary Stinton
Monterey and Cottle Roads
San Jose 95193

Resource Management Associates
Dr. Jerry Orlob
3700 Mount Diablo Boulevard
Lafayette 94549

Stanford Research Institute
Dr. Shonh Lee
333 Ravenswood Avenue
Menlo Park 94025

Stanford Research Institute
Dr. William R. Mabey
333 Ravenswood Avenue
Menlo Park 94025

Tetra Tech, Incorporated
Dr. Carl W. Chen
Environmental Systems Engineering
3700 Mount Diablo Boulevard
Lafayette 94549

University of California
Dr. Hugo Fisher
Hydraulic Laboratory
Berkeley 94720

University of California
Dr. Kent Wilson, Professor
Department of Chemistry
La Jolla 92037

Water Resources Engineers,
Incorporated
Dr. Dan Envanson, Vice-President
710 South Broadway
Walnut Creek 94596

Water Resources Engineers,
Incorporated
Dr. Larry Roesner
710 South Broadway
Walnut Creek 94596

FLORIDA

University of Florida
Dr. James M. Davidson, Professor
Soil Science Department
2169 McCarty Hall
Gainesville 32611

INDIANA

Purdue University
Dr. Robert Bonczek
Department of Management and
Computer Science
Krannert Building
West Lafayette 47907

Purdue University
Dr. Andrew Whinston, Professor
Department of Management
Krannert Building
West Lafayette 47907

IOWA

Iowa Department of Environmental
Quality
Dr. Dennis Arthur Quan
3920 Delaware Avenue
P.O. Box 3326
Des Moines 50316

MARYLAND

Agricultural Research Center
Dr. Edwin T. Engman, Chief
Building 007, ARC-West, Room 139
Beltsville 20705

University of Maryland
Dr. James E. Ayars
College of Agriculture
Department of Agricultural
Engineering
College Park 20742

University of Maryland
Dr. Lamar Harris, Chairman
Agriculture Engineering
Shriver Laboratory
College Park 20742

University of Maryland
Dr. H.N. Holtan, Lecturer
Agriculture Engineering Department
College Park 20742

MASSACHUSETTS

Clark University
Dr. Harry F. Schwarz, Professor
Environmental Affairs
Worcester 01601

Harvard University
Dr. J. Carrell Morris
Division of Engineering and Applied Physics
127 Pierce Hall
Cambridge 02138

Massachusetts Institute of Technology
Dr. David H. Marks, Professor
Ralph M. Parsons Laboratory for Water Resources and Hydrodynamics
Department of Civil Engineering
Building 48-305
Cambridge 02139

Massachusetts Institute of Technology
Dr. Nicolas P. Negroponte
Department of Computer Graphics
Cambridge 02139

Massachusetts Institute of Technology
Dr. Keith Stolzenback
Ralph M. Parsons Laboratory for Water Resources and Hydrodynamics
Department of Civil Engineering
Building 48-305
Cambridge 02139

Resource Analysis, Incorporated
Dr. Brendan M. Harley, President
Hydrology - Water Resource Systems - Public Systems
1050 Massachusetts Avenue
Cambridge 02138

Resource Analysis, Incorporated
Dr. Guillermo J. Vincens
Hydrology - Water Resource Systems - Public Systems
1050 Massachusetts Avenue
Cambridge 02138

University of Massachusetts
Dr. Warren Litsky
Department of Environmental Sciences
Amherst 01002

MISSISSIPPI

Corps of Engineers, U.S. Army
Dr. Rex Eley
Waterways Experiment Station
P.O. Box 631
Vicksburg 39180

Corps of Engineers, U.S. Army
Mr. Donald L. Robey
Waterways Experiment Station
P.O. Box 631
Vicksburg 39180

Corps of Engineers, U.S. Army
Mr. Thomas Walski
Waterways Experiment Station
P.O. Box 631
Vicksburg 39180

MONTANA

Montana State University
Dr. Donald W. Boyd, Associate Professor
Department of Industrial Engineering and Computer Sciences
Bozeman 50715

Montana State University
Dr. David G. Stuart, Director
Water Resources Research Center
349 Reid Hall
Bozeman 59715

NEW JERSEY

Rutgers University
Mr. William Whipple
Water Resources Research Institute
Cook College Campus
New Brunswick 08903

NEW MEXICO

Computer Graphics
Dr. Melvin L. Prueitt, President
Los Alamos Scientific Laboratory
Los Alamos 87544

NEW YORK

Brookhaven National Laboratories
Computer Center
Upton, Long Island 11973

City University of New York
Dr. Eric Posnentier
Institute of Marine and Atmospheric Science
675 West 252nd Street
Bronx 10471

International Ozone Institute
Dr. Myron E. Browning, Managing Director
Skytop Merrill Lane
Syracuse 13210

New York Ocean Science Laboratory
Dr. Hollman
P.O. Drawer EE
Montauk 11954

Rensselaer Polytechnic Institute
Dr. Richard A. Park
Freshwater Institute and Department of Geology
Troy 12181

State University of New York
Dr. Robert A. Sweeney, Director
1300 Elmwood Avenue
Great Lakes Laboratory
Buffalo 14222

Syracuse Research Corporation
Dr. Lionel H. Naum, Director
Merrill Lane
Syracuse 13210

NORTH CAROLINA

North Carolina State University
Dr. Irving S. Goldstein, Head
Department of Wood and Paper Science
Box 5488
Raleigh 27607

North Carolina State University
Dr. R.G. Hitchings, Professor
School of Forest Resources
Robertson Pulp and Paper Laboratory
Box 5516
Raleigh 27607

OHIO

Ohio State University
Dr. Robert C. Steifel, Director
Water Resources Center
1791 Neil Avenue
Columbus 43210

W.E. Gates and Associates, Incorporated
Dr. Richard M. Males
1515 Cincinnati-Batavia Pike
Batavia 45268

Youngstown State University
Dr. Michael Householder, Chairman
Department of Chemical Engineering
Youngstown 44555

OREGON

Environmental Protection Agency
Dr. Mustafa Shirazi
Corvallis 97330

TENNESSEE

Oak Ridge National Laboratory
Dr. W.R. Emanuel
Environmental Sciences Division
P.O. Box X
Oak Ridge 37830

Oak Ridge National Laboratory
Dr. Dale D. Huff
Environmental Sciences Division
P.O. Box X
Oak Ridge 37830

Oak Ridge National Laboratory
Dr. D.C. Parzyck
Environmental Sciences Division
P.O. Box X
Oak Ridge 37830

Oak Ridge National Laboratory
Dr. M.R. Patterson
Environmental Sciences Division
P.O. Box X
Oak Ridge 37830

Oak Ridge National Laboratory
Dr. John Shepard
Environmental Sciences Division
P.O. Box X
Oak Ridge 37830

Oak Ridge National Laboratory
Dr. H.H. Shugart
Environmental Sciences Division
P.O. Box X
Oak Ridge 37830

TEXAS

Texas Instruments, Incorporated
Dr. Robert Stratton, Director
Central Research Laboratories
P.O. Box 5936
Dallas 75222

UTAH

Utah State University
Dr. David Bowles
Water Resources Research, UMC 68
Logan 84322

VIRGINIA

Virginia Polytechnic Institute and
State University
Dr. Charles W. Steger
Division of Environmental and Urban
Systems
Blacksburg 24061

U.S. Department of the Interior
Geological Survey
Dr. U.S. McKelney, Director
Reston 22092

WISCONSIN

University of Wisconsin
Dr. John A. Hoopes, Professor
Department of Civil Engineering
Madison 53706

University of Wisconsin
Dr. Byron H. Shaw
School of Natural Resources
Stevens Point 54481

CANADA

University of Toronto
Dr. D. Mackay, Professor
Department of Chemical Engineering
and Applied Chemistry
Toronto, Ontario M5S 1A4

FRANCE

ARLAB
Dr. Yves Emsellem, President
Directeur General
Service de l'Environnement et de la
Protection des Consommateurs
Sophia-Antipolis, Valbone 06560

Appendix E

LIST OF PARTICIPANTS

(Listed in alphabetical order by institutions)

This list represents the various universities, firms and institutions who participated and contributed their expertise toward the major problems and issues that were identified and discussed during the several site visitations and lengthy telephone calls made during the course of this investigation.

Agricultural Research Center
Dr. Edwin T. Engman, Chief
Building 007, ARC-West, Room 139
Beltsville, MD 20705

Compass Systems, Incorporated
Dr. Roger A. Bauer, President
4640 Jewell Street, Number 204
San Diego, CA 92109

City University of New York
Dr. Eric Posnentier
Institute of Marine and Atmospheric Science
675 West 252nd Street
Bronx, NY 10471

Corps of Engineers, U.S. Army
Dr. Rex Eley
Mr. Donald L. Robey
Mr. Thomas Walski
Waterways Experiment Station
P.O. Box 631
Vicksburg, MS 39180

Department of Water Resources
Mr. Richard J. Lerseth
Delta Branch, Environmental Studies
Sacramento, CA 95814

Environmental Dynamics, Incorporated
Dr. John A. Dracup, President
1609 Westwood Boulevard, suite 202/3
Los Angeles, CA 90024

Hydrocomp, Incorporated
Dr. Norman H. Crawford, President
Mr. Jean Jacques Heler
1502 Page Mill Road
Palo Alto, CA 94304

Hydrologic Engineering Center
Corps of Engineers, U.S. Army
Dr. Jess Abbott
Dr. Jerry R.G. Willey
609 Second Street
Davis, CA 95616

Iowa Department of Environmental Quality
Dr. Dennis Arthur Quan
3920 Delaware Avenue
P.O. Box 3326
Des Moines, IA 50316

Massachusetts Institute of Technology
Dr. David H. Marks, Professor
Ralph M. Parsons Laboratory for Water Resources and Hydrodynamics
Department of Civil Engineering
Building 48-305
Cambridge, MA 02139

Montana State University
Dr. Donald W. Boyd, Associate Professor
Department of Industrial Engineering and Computer Sciences
Bozeman, MT 50715

Montana State University
Dr. David G. Stuart, Director
Water Resources Research Center
349 Reid Hall
Bozeman, MT 59715

New York Ocean Science Laboratory
Dr. Hollman
P.O. Drawer EE
Montauk, NY 11954

Oak Ridge National Laboratory
Dr. Dale D. Huff
Environmental Sciences Division
P.O. Box X
Oak Ridge, TN 37830

Ohio State University
Dr. Robert C. Steifel, Director
Water Resources Center
1791 Neil Avenue
Columbus, OH 43210

Purdue University
Dr. Robert Bonczek
Dr. Andrew Whinston, Professor
Department of Management and Computer Science
Krannert Building
West Lafayette, IN 47907

Raytheon Company
Dr. Stan Chamberlain, Manager
Systems Analysis Group
Oceanographic and Environmental Service
Box 360
Portsmouth, RI 02871

Resource Analysis, Incorporated
Dr. Brendan M. Harley, President
Dr. Guillermo J. Vincens
Hydrology - Water Resource Systems - Public Systems
1050 Massachusetts Avenue
Cambridge, MA 02138

Rensselaer Polytechnic Institute
Dr. Richard A. Park
Freshwater Institute and Department of Geology
Troy, NY 12181

Stanford Research Institute
Dr. William R. Mabey
Dr. Shonh Lee
333 Ravenswood Avenue
Menlo Park, CA 94025

Tetra Tech, Incorporated
Dr. Carl W. Chen
Environmental Systems Engineering
3700 Mount Diablo Boulevard
Lafayette, CA 94549

University of Maryland
Dr. James E. Ayars
Dr. Lamar Harris
Department of Agricultural Engineering
College Park, MD 20742

Utah State University
Dr. David Bowles
Water Resources Research, UMC 68
Logan, UT 84322

Virginia Polytechnic Institute and State University
Dr. Charles W. Steger
Division of Environmental and Urban Systems
Blacksburg, VA 24061

Water Resources Engineers, Incorporated
Dr. Dan Envanson, Vice-President
Dr. Larry Roesner
710 South Broadway
Walnut Creek, CA 94596

W.E. Gates and Associates,
Incorporated
Dr. Richard M. Males
1515 Cincinnati-Batavia Pike
Batavia, OH 45268

Youngstown State University
Dr. Michael Householder, Chairman
Department of Chemical Engineering
Youngstown, OH 44555

Appendix F

LIST OF TRIPS TO CONFERENCES AND SITE VISITS

CONFERENCES ATTENDED

1. Symposium on — Nonbiological Transport and Transformation of Pollutants on Land and Water. National Bureau of Standards, Gaithersburg, MD, 11-13 May 1976.

2. Conference — The 1976 National Computer Conference. New York, NY, 7-10 June 1976.

3. Conference — The 1976 American Statistical Association. Boston, MA, 22-26 August 1976. The author presented a paper at this meeting entitled "On the Sum of Truncated Gamma Distributions."

TRAVEL MADE TO THE FOLLOWING SITES (listed in alphabetical order by state)

USA

California	Berkeley	University of California
	Davis	The Hydrologic Engineering Center
	Lafayette	Resource Management Associates
		Tetra Tech, Incorporated
	Menlo Park	Stanford Research Institute
	Palo Alto	Hydrocomp, Incorporated
	Stanford	Stanford University
	Walnut Creek	Water Resources Engineers
Indiana	West Lafayette	Purdue University
Maryland	College Park	University of Maryland
Massachusetts	Amherst	University of Massachusetts
	Bedford	Tufts University
	Boston	University of Boston
	Cambridge	Harvard University
		Massachusetts Institute of Technology
Mississippi	Vicksburg	U.S. Army, Corps of Engineers
New Jersey	New Brunswick	Rutgers University

New York	Albany	State University of New York
	Brookport	State University of New York
	New York	City University of New York
	Oswego	State University of New York
	Troy	Rensselaer Polytechnic Institute
Ohio	Cleveland	Cleveland State University
		Case Western Reserve University
	Columbus	Battelle Memorial Institute
		Ohio State University
	Kent	Kent State University
Vermont	Burlington	University of Vermont
Canada		
Quebec	Montreal	McGill University
France		
Valbone	Sophia-Antipolis	ARLAB
		Service de l'Environnement

Appendix G

LIST OF COMPUTER COLOR GRAPHICS FILMS

The following list of computer color graphics films were presented along with the final report of this feasibility study to the U.S. Environmental Protection Agency in Athens, GA, on 23 November 1976. These films were utilized to exemplify and demonstrate the advantages and possibilities of computer color graphics toward the application of future water quality modeling.

1. Source: Los Alamos Scientifics Laboratory
   Dr. M.L. Prueitt, President
   Computer Graphics
   Los Alamos, NM 87545

   Film Titles:
   a. Interactive Graphics at LASL.
   b. Physical Simulation with Computer Color Graphics.
   c. Computer Color Generations.

2. Source: Sandia Laboratories
   Mr. Robert Colgan
   Box 5800
   Motion Picture Production Division
   Albuquerque NM 87115

   Film Title: Computer Graphics at Sandia Laboratories.

3. Source: University of California at San Diego
   The Sensus Bureau
   Dr. Kent Wilson
   Department of Chemistry
   La Jolla, CA 92037

   Film Title: The Human Brain -- A Dynamic View of Its Structures and Its Organization Using Computer Color Graphics.